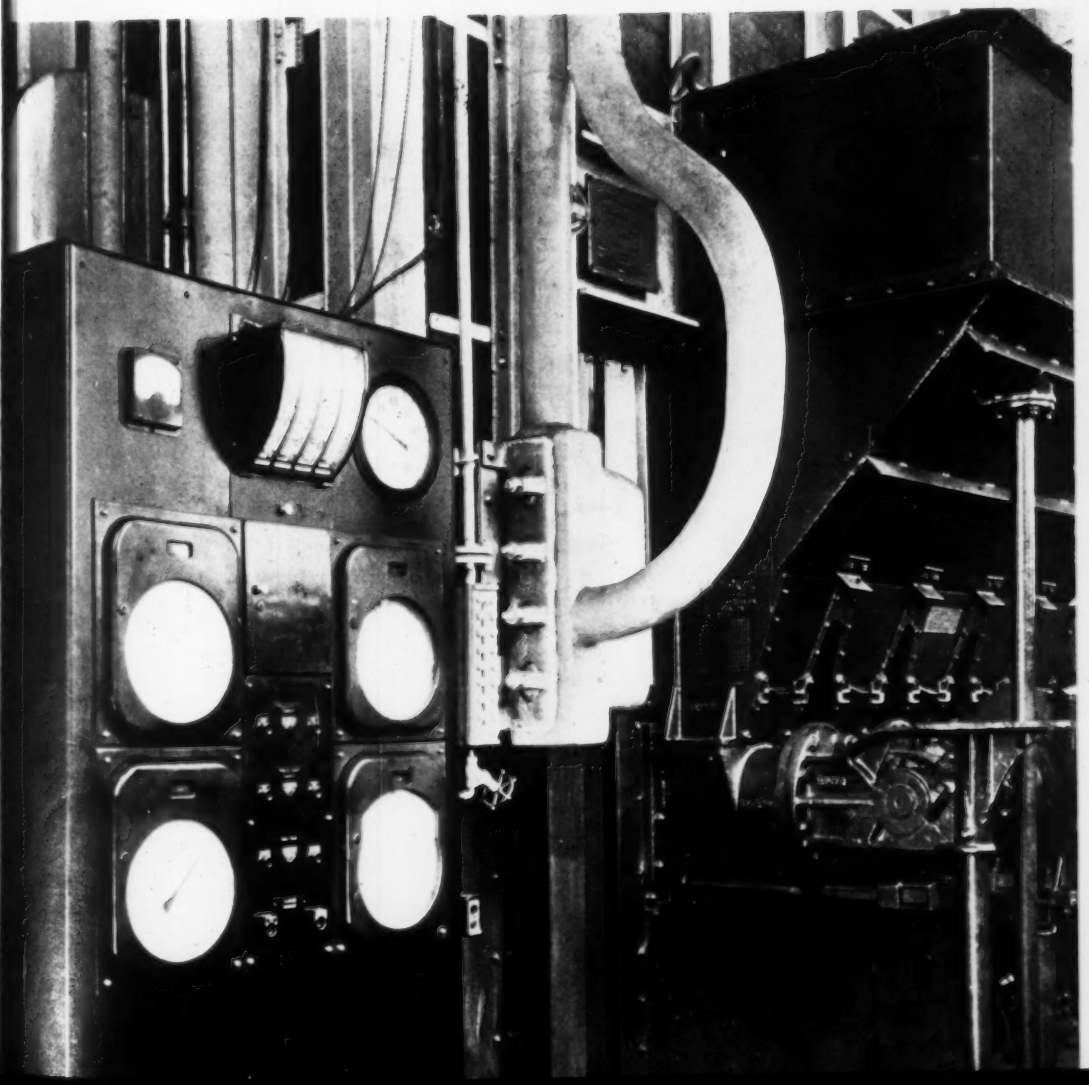
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL



VOLUME 9

SEPT. 1936

NUMBER 9

THE GIANT 200-*inch*

An Achievement in Glass-Making *and in Temperature Control*

Science will mark 1936 as the year in which the giant disk for the California Institute of Technology Observatory, located on Mt. Palomar, was successfully produced by the Corning Glass Works. It opens up exciting possibilities in astral exploration—the extent of which no one can foretell.

We at Foxboro are proud of having been permitted to play a small part in the success of this undertaking. To sixteen Foxboro Potentiometer Controllers was entrusted the task of maintaining exact annealing temperatures during the year that the disk was in a lehr. Utmost accuracy was vital, because temperatures were lowered very gradually—sometimes at the rate of less than a degree per day. As this is written, examination of the rim of the disk with polarized light indicates a residual stress that is symmetrical about the center of the disk and of low order, thus fulfilling the two requirements of the practically perfect annealing demanded of glass disks that are to be fashioned into telescope mirrors.

This is but an interesting example of many less spectacular but equally important problems in Instrumentation which we are solving every day, in practically every industry. If your manufacture involves temperature, pressure, rate of flow, humidity or liquid level, we are able to help you, too.

THE FOXBORO COMPANY
16 NEPONSET AVE., FOXBORO, MASS., U.S.A.
Branch Offices in 25 Principal Cities

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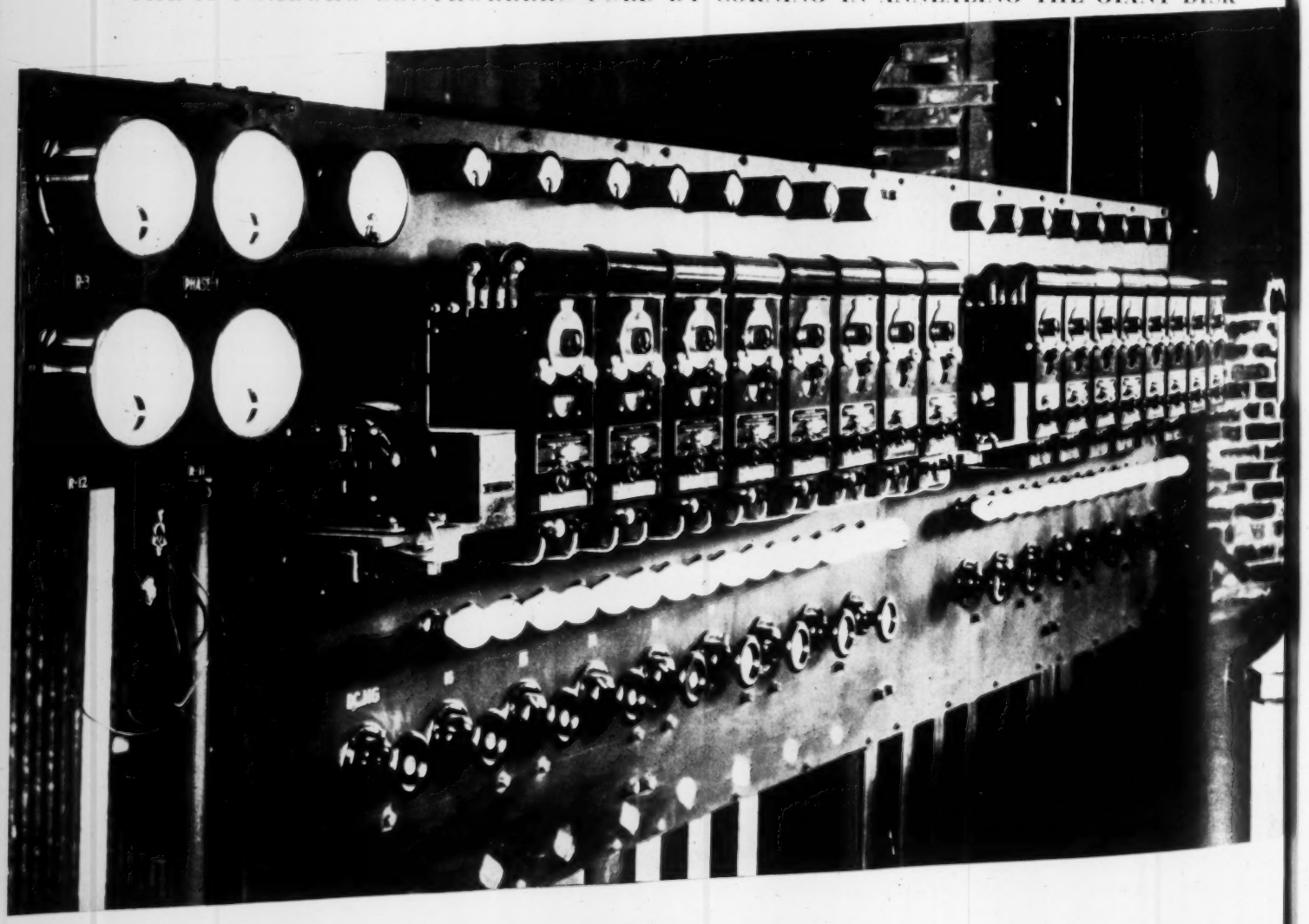
COMPLETE INDUSTRIAL INSTRUMENTATION

THE 16 FOXBORO CONTROLLERS USED BY CORNING IN ANNEALING THE GIANT DISK



MODERN TAYLOR RECORDING THERMOMETER. For applications within minus 100° F. and plus 1000° F. Face- or flush-mounted cases. Dust-proof and moisture-proof. *Taylor Recording Pressure Gauges* are similar in appearance. Interchangeable tube systems make conversion from Pressure Gauge to Recording Thermometer easy.

Write accurate records

for today and tomorrow

...WITH TAYLOR RECORDING THERMOMETERS AND PRESSURE GAUGES

THE modern Taylor Recording Instrument assures a more accurate record of temperature and pressure than was obtainable before. Its efficient and economical operation guards today's profits against waste and high production costs. And it makes future processing a clearer picture in the light of past records.

Taylor Recording Instruments are designed to meet the most exacting requirements in the chemical industry. They are built to last longer. A simplified and refined mechanism, light in weight but sturdy and durable, and practically frictionless, instantaneously translates temperature or pressure into pen arm action.

The construction of Taylor Recording Instruments makes them adaptable to any temperature or pressure need. Temperature Recorders, for example, are of three types—mercury-, gas-, and vapor-actuated. With the mercury-actuated type is available one of the most important aids to accuracy ever developed. This is Taylor Accuratus Tubing, an exclusive, patented product that automatically compensates for all temperature differences surrounding the tubing between bulb and instrument. It assures a true bulb temperature record. It permits installations of the recorder at unusual distances from the bulb.

Write for Taylor Catalog 68J for further data on Temperature Recorders. Get Catalog 68JF for more information on Taylor Recording Pressure Gauges.

For first-hand information on these and all other Taylor Instruments for controlling temperature, pressure, rate of flow or liquid level, ask a Taylor Representative to come and discuss their application with you. Address Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada. Manufacturers in Great Britain—Short & Mason, Ltd., London, England.

Taylor

Indicating Recording Controlling

TEMPERATURE, PRESSURE *and* **FLOW INSTRUMENTS**

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

As old readers know, *Instruments* has a rigid policy with regard to descriptions of commercial devices emanating from manufacturers: we boil them down and print them in the monthly New Instruments Department; we exclude them from the feature-article pages; and we insist that articles be free of commercial taint. You may wonder, therefore, why this month's leading article describes an instrument which is for sale and horrors! is written by the vice-president of the company that sells it. However, before you write to The Instruments Publishing Company that we should be fired, read the article! Fact is, since Wiley Post made his solo flight around the world with the aid of an automatic pilot, *you* have wanted an article on automatic flight and we have therefore been trying to get it. Our acquaintances in the aviation industry told us from the start that "automatic flight" meant the use of the Gyropilot; that no one was better qualified to write it up than Preston Bassett, and that he was as commercially-minded as a new-born babe. So *we* hunted up Bassett two years ago and kept on asking him to tell *you* all about it. This is not an apology but a re-statement of our policy.

Paul MacGahan's article, too, might be considered the result of a slip in our policy, so we hasten to report that the instrument he describes is not being produced commercially.

Ralph Batcher begins this month a series of authoritative articles on the classification of oscillograms and on the production of various types for convenient interpretation.

Again our Electrical Measurements and Control serial describes modern automatic regulators—this month the electronic types.

This month's New Instruments Department reports an unusually varied crop, including interesting coincidences which you'll discover for yourself.

WELL WORTH $3,500,000

IN a world where "might-makes-right" nations tear up treaties and arm for aggression on peace-loving peoples, our security depends in large measure upon constant naval, merchant-marine and seaplane engineering advances.

These advances, particularly in the fields of hull lines, correct propeller design for each hull type, determination of required power, improvements in turning qualities, behavior among waves, performance in shallow water, etc., depend upon ceaseless experimenting with numerous models towed under definite conditions in adequate model basins equipped with many types of instruments.

Designed in 1895 and completed in 1900, the model basin at Washington is obsolete. Its total length is 470 feet; its uniform section length 280 feet; its length for taking the most significant data (allowing for carriage acceleration and deceleration) is a paltry 100 feet. Michigan University's basin, modern in some respects, is only 300 feet over-all, hence likewise utterly inadequate for suitable-scale models of seaplane floats and hulls and even of high-speed surface craft.

Germany, Japan and Italy, in the order named, now have the world's biggest model basins. Russia's, when completed, will lead: with a length of 3280 feet. Germany, Japan, Italy, Russia!

For six years, efforts have been made to have Congress appropriate $3,500,000 (0.5% of this year's Navy appropriation) for a new model basin with shops and laboratories as recommended by the Hoover and Roosevelt administrations, by the American Engineering Council and by numerous scientific and technical societies. Democratic and Republican legislators, mostly representing the citizenry of non-coastal states, we believe, have defeated these efforts.

Verily, this is a case where the citizenry has been acting like a yokelry. The proposed model basin would serve not only the Navy which protects the prairie states as much as California or New York, but it would pay for itself in three years or less by cutting the Navy's costs for hull-design, etc. Moreover, it would be about 50% self-liquidating through fees from private companies. A propos, it is said that our shipping interests use the model basins of foreign nations, which pocket American dollars and "borrow" American ideas.

Extracts from House Naval Affairs Committee hearing:

ADMIRAL LAND. It is a highly technical research laboratory . . . and vitally important. . . . If you look at what other countries have today and have obtained recently, I think you would all feel ashamed of our position in this matter. . . .

MR. DARDEN. I do not think we have had a more important matter before this committee in a long time. . . . The wind tunnel at Langley Field has been of enormous benefit in airplanes. . . . This is the same thing with reference to ships. . . .

MR. BLAND. We cannot keep abreast of the times in international matters unless we are prepared to secure scientific knowledge in a scientific way. . . . Our engineers will enable the ship to go through the water with greater speed but using less fuel. . . . This means economic saving to the people of the United States. * * *

ADMIRAL SMITH. . . . The remainder, $1,870,000 representing materials manufactured . . . Carriages and scientific instruments, $245,000. * * *

MR. SCOTT. I did not want anything in America to be patterned after Russia.

THE CHAIRMAN. We know that. * * *

THE CHAIRMAN. The ayes have it and the bill is ordered favorably reported.

Instruments readers can do patriotic work and serve science and industry by supporting the Model Basin Establishment Bill to be re-introduced in the coming session. Start writing to your Senators and Representatives and get their promises *now*, before elections.

INSTRUMENTS' READERS AT WORK

No. 17

GEORGE M. DEMING

Engineer, Apparatus Research & Development Department

AIR REDUCTION SALES COMPANY

Laboratory, Jersey City, N. J.

By M. F. BEHAR

IF you were an *Instruments* subscriber three years ago you no doubt read, in the September 1933 issue, a fascinating article of some 6000 words, with ten figures, on new principles of high-pressure gas regulation; and in the editorial page column entitled "In This Issue" the following appraisal:

> Three months ago the mail brought a manufacturer's announcement of what looked like "just another" pressure regulator, but excitement gripped us when we discovered that it had an almost unbelievably "flat" regulation characteristic. Smelling a back-of-the-news story that *Instruments* readers would enjoy, we went a-hunting for the inventor, and finally ran him down in his den behind formidable No Admittance signs in the Airco research building in Jersey City.
>
> Preconceived notions—those devils that blind many solution-seeking engineers—never had a chance to hamper George M. Deming, for when he began his five-year work on the problem of high-pressure gas regulation he threw overboard existing designs which were supposed to be "perfected." He started from scratch as if no gas regulator had ever been developed by anyone else, but he never failed to profit by the experience of others: whenever he found himself on a previously-traveled road leading to mediocrity, he resolutely left it to explore untrodden paths in search of excellence.

You no doubt felt, and still feel, that it would be a pleasure to be introduced to that man Deming.

We feel that it would be a pleasure to introduce Deming to you. Which (since he, too, is an old time subscriber) we can proceed to do by means of this page.

Born in San Bernardino, Calif., in 1893, Deming found his early life arduous, his father's illness and business failure forcing him to alternate work and schooling. During his last year of high school he met with an accident that undermined his own health for ten years. It took him a nine years' struggle to complete a four-year college course and to save money for his course at the University of Seattle beside paying hundreds of dollars to doctors and hospitals and assisting his father. Class work by day at the university and a full eight-hour shift at night—until he broke down completely in the middle of his Junior year.

Recovered, he taught mathematics and science in a Washington State high-school.

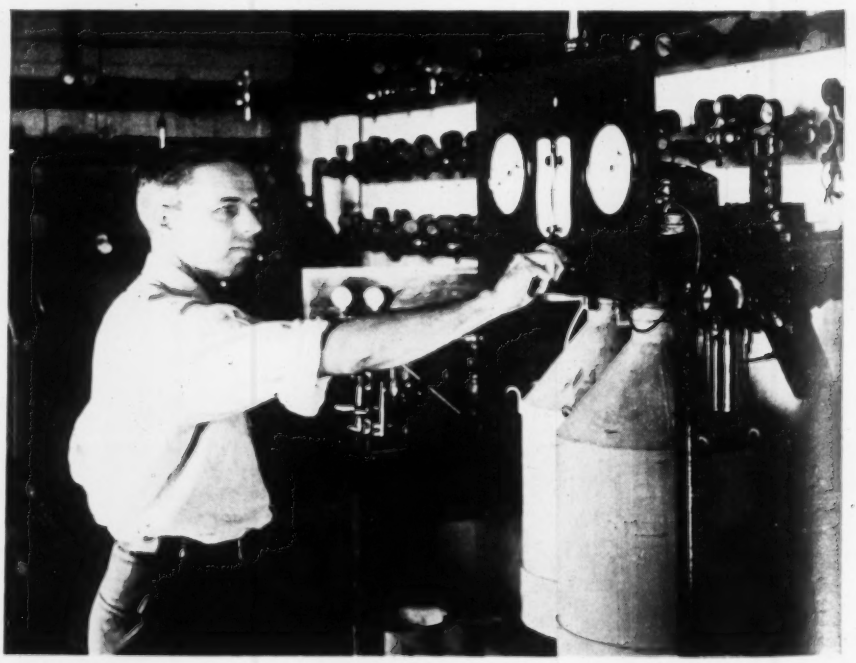
Then military service—in the Experimental Station of the U. S. Army Chemical Warfare Service, the latter period under Dr. Richard Tolman. The war over, he joined the Bureau of Standards as laboratory assistant, was promoted to Assistant Engineer Physicist, designed test equipment and supervised the Bureau's tests of oxy-acetylene torches. Then back to complete his engineering course, which he did at the University of Washington, taking his B.S. in Chem.Eng. in 1922.

Followed two years of telephone machine-switching design, and a few months as examiner in the U. S. Patent Office, from which, in 1925, he went to Airco's Apparatus Research and Development Department.

Deming's inventions cover the fields of pressure regulators, welding and cutting apparatus, flowmeters, acetylene generators and gas distributing systems. Thanks to him, pressure regulators have jumped from a minor to a major position in Airco's apparatus sales, now ranging from precision models to 50,000-ft.³/hr. sizes for steel mills.

INSTRUMENTS USED IN DEMING'S SECTION OF AIRCO'S APPARATUS RESEARCH AND DEVELOPMENT DEPARTMENT

- Crosby gage tester.
- American gage tester.
- Arthur H. Thomas density balance.
- Arthur H. Thomas chemical balance.
- Riehle 100,000-lb. testing machine.
- Brinell hardness tester.
- Rockwell hardness tester.
- Scleroscope hardness tester.
- Riehle Charpy impact tester.
- Thomas Grinder Co. fatigue tester.
- Leeds & Northrup potentiometer.
- Leeds & Northrup temperature recorder-controller.
- National oscilloscope.
- Leitz photomicrographic equipment.
- Huggenberger extensometers & accessories.
- Whittemore strain gage.
- Ames dial micrometers.
- Shore Durometers.
- Also special equipment for specific purposes such as corrosion investigations, valve testing, etc.



DEMINGSTRATING THE WORLD'S LARGEST OXYGEN REDUCING VALVE

THE MONTH'S NEW INSTRUMENTS

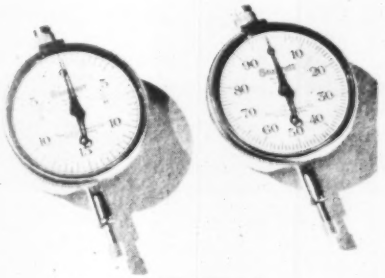
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Dial Indicators

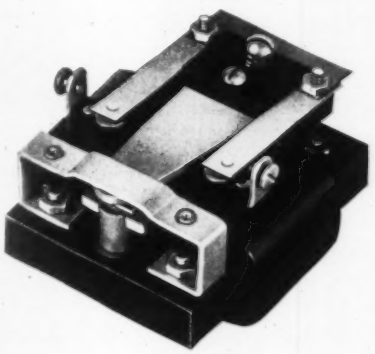
These new dial indicators are completely rust proof: gears, rack, dowels, screws, stem and bushings being stainless steel and case and bezel chromium



plated. The back is a solid die casting, recessed to hold the lug for clamping indicator to machines, jigs or fixtures. Lug is attached on or off center and can be turned parallel or at right angles to axis of spindle. Case is a die casting, concentrically machined, with stem cast integral for maximum strength. Genuine sapphire jewels are used; all gears and pinions are cut and finished. Dials are finished with an easily cleaned enamel; crystal is said to be non-breakable. Dial may be moved and locked by means of knurled bezel and clamp, to bring zero mark to any point in relation to the hand. *L. S. Starrett Co., Athol, Mass.*

Relay Transformer

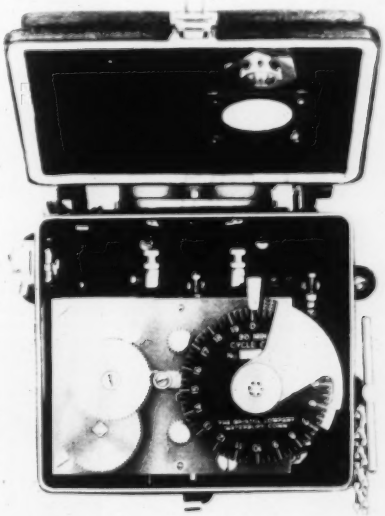
Makers have employed this device for upward of a year in their own control and relay outfits, now place it on market for embodiment in numerous types



of control and signaling systems. It combines a low-voltage transformer and a line voltage relay; is available for either 110 or 220 volts, is listed by Underwriters; has 3-point armature contact, including two milled knife edges with proper phase splitting to prevent a-c. hum. Balanced armature design with long contact arms but low moment of inertia is said to give accelerated switch action insuring conservative ½ hp. rating. Operates satisfactorily in any position, armature always completing half its motion before break occurs, insuring quick break. Size 3" × 3¼" × 2½". —*Russell Electric Co., 536 Huron St., Chicago, Ill.*

Process Cycle Controller

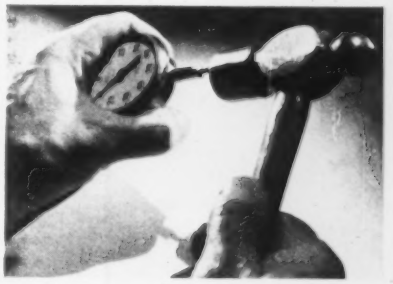
Particularly designed for platen-press and other variable-speed applications in the rubber and molded-plastics industries, this latest addition to maker's line of process cycle controllers, designated as "Model 6088-V," is characterized by adjustable features whereby cures can be altered to conform to changes made necessary by changes in dies or in materials. The controller is self contained



Its motor operates one, two or three leakless three-way pilot valves especially designed for use in process cycle controllers; without air leak and permitting air to be admitted to or released from diaphragm-motors (or other pneumatic power devices) as fast as desired. Though equipped with but a single cam, this controller makes possible a multiplicity of adjustable cycles by reason of a two-speed cam-operating mechanism, said to be novel, which at end of cycle automatically speeds up cam rotation approx. 100 times to reset cam to starting position for next cycle, whereupon cam motor stops to await operator's signal for new cycle. Motor is of synchronous, capacitor type, totally enclosed and factory-lubricated for instrument life, with high starting torque, and using 7 watts. By reason of three-way air valves, compressed air supply need only be 25 lbs./in.². *The Bristol Co., Waterbury, Conn.*

"Shockless" Dial Gage

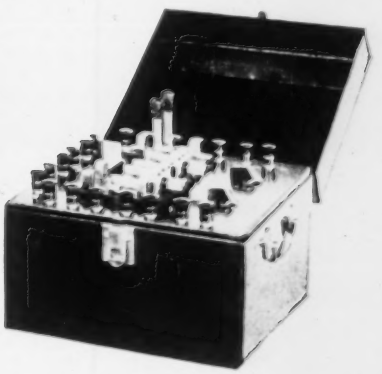
Illustration brings out reason for new "No. 56" and "No. 57" gages being designated as "Shockless"; shock-absorbing wheel assembly is leading feature. Other



features: removable case stem and spindle, no screw point, wire-attached bezel, solid steel back, short spindle with coarse rack, cup dial and straight-line hand, no spring under dial. Most of these features are new and patented. "No. 56" is 2¼" diam., "No. 57" is 3½" diam. Both have 0.3" maximum spindle travel; are available in four dial graduations, indicating to 0.001" or 0.0001". "No. 57A" metric gage has 7.5 mm. max. spindle travel and indicates to 0.01 mm. All are available either in plain-bearing models, or completely jeweled with genuine sapphires. *B. C. Ames Co., Waltham, Mass.*

Portable Testing Box for Relays

A new portable testing box for distance, reactance, or impedance relays weighs 15 lbs., is approx. 9"×10"×7½" when closed, and is used with external



resistors and reactors which are also portable. It makes it possible for one man to perform in the field all tests directly related to the setting of the relay and its operation under fault conditions. Arc resistance is simulated by an adjustable resistor. No phase angle meter is necessary, and the only calculation needed is the multiplication of the fault reactance by a dial setting. Relay setting not being based on instrument readings, errors of reading or calibration are eliminated. Connections can be made in a few minutes. If test blocks are used the box can be immediately transferred from one relay to the next. —*General Electric Co., Schenectady, N. Y.*

An Entirely New Potentiometer

MODEL C

PORTABLE POTENTIOMETER

The calibration of this potentiometer is established by basic physical properties of elements.

No standard cell or other chemical device subject to deterioration is employed to standardize this instrument.

It is the most rugged, most reliable and foolproof portable potentiometer ever built.

The operation of this instrument differs in no respect from the old style potentiometers employing standard cells.

Accurate and reliable in the hands of the technician, safe from damage in the hands of the workman.

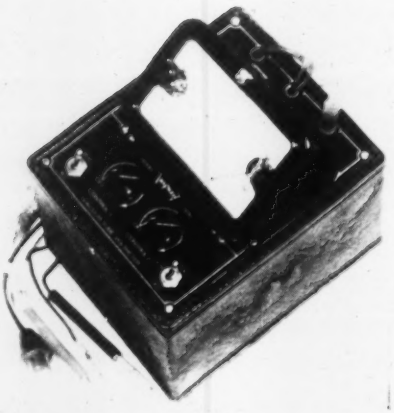
Completely self contained.

- Size 6″ x 7″ x 4″
- Weight four pounds.
- Beautifully finished molded Bakelite throughout.

Write for full details.

HURL R. ADAMS

Alhambra Way Pittsburgh, Pa.

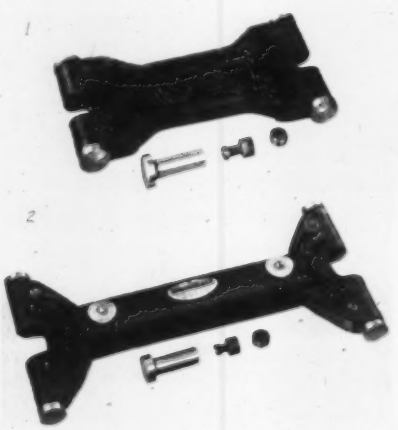


Vacuum Tube Voltmeter

New "Model 1250" vacuum tube voltmeter is said to be self-calibrating; with accuracy independent of changing tube values. There has been developed a new tube bridge circuit for this model, whereby the tube characteristics are stabilized with the circuit, irrespective of what the tube emission values may be. It is thereby self-calibrating and its stability in giving accurate readings is said to be assured. Instrument's purpose is measuring low a-c. and d-c. voltages without current drain. It has Triplett twin indicators (tilting type), one is a galvanometer that indicates when the bridge is in balance; the other is a three-range voltmeter with linear scales reading in peak a-c. and d-c. voltages. Ranges are 2.5, 10 and 50 volts. Case is metal with black wrinkle finish. Silver and black panel. Case size, 7¾"x6⅝"x4⅝". —*The Triplett Electrical Instrument Co., Bluffton, Ohio.*

Adjustable Plug Gages

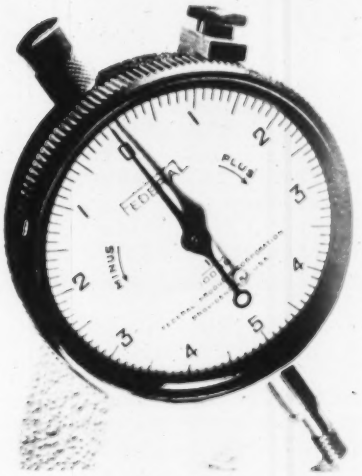
A new line of adjustable plug gages is announced in two types said to provide complete coverage in sizes. Fig. 1 shows type furnished in sizes <4"; Fig. 2 shows type covering remaining sizes.



Twenty-three standard sizes: min. of 2½" to a max. of 12½"; also specials. Frames are of a specially heat treated and seasoned alloy iron. Positiveness of lock is achieved by using a flat on a lock bushing, which by screw adjustment binds against a straight flat on the anvil. Gages may be furnished either with button or pin type anvils. —*Sheffield Gage Corporation, Dayton, Ohio.*

Dial Indicators

In these new "Low Friction" dial indicators, full-jeweled construction, advanced design and minimization of weight of moving parts has permitted the use



of a low-pressure spring, resulting in what is described as "extremely light and free action enabling indicator point to follow surface variations . . . precisely and quickly." It is said that indicator point "does not bounce." —*Federal Products Corp., 1144 Eddy St., Providence, R. I.*

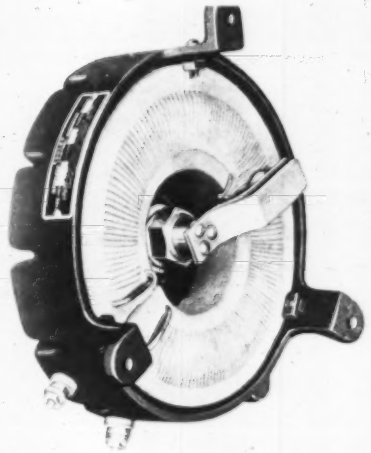
"Shadowgraph" Scales

This new over- and under-weight scale indicates by a shadow on an illuminated dial—a design which eliminates all indicating mechanism and thereby reduces working parts by 30%, it is said. Parallax errors are rendered impossible. It is claimed also that the new "Shadowgraph" is capable of registering 100% more travel per ounce of weight on the

dial, at no sacrifice to speed of operation. Working parts such as the balance ball, beam and poise, weights and weight rack are completely enclosed, except for commodity or weighing platter. The "Shadowgraph" may be moved from one operation to another without leveling. "No matter how rough or uneven work benches may be, this scale functions perfectly." All models equipped with carrying handles, are noiseless in operation, have rubber mountings; are oil-dashpot controlled for speed of operation. Illumination of dial is provided by standard auto lamp bulbs—any bayonet base double-contact 21 or 12 candlepower. —*Exact Weight Scale Co., Columbus, Ohio.*

Industrial Rheostat

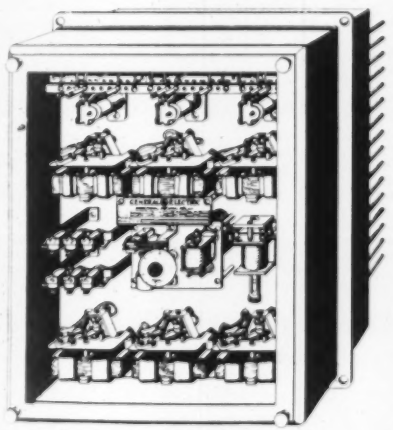
...l to have "extraordinary ability to ...n overloads," this new rheostat has ...-iron frame into which is mounted ...ular block of the same refractory



material which is used in manufacture of "Dorreco" heating elements. Into this material is embedded a closely-wound resistor coil, which a metal-graphite button contacts under spring pressure. *Cooley Electric Furnace Co., 1411 E. 30th St., Indianapolis, Ind.*

High-speed Directional Distance Relay

Combining in one relay all the functions of the three commonly required devices, a new high-speed, 3-phase, directional distance relay, "Type GCX12A," requires simply connecting the current and potential transformer leads and the control circuits to studs on the case to complete the installation. It consists of three starting units, three resistance units, and one timing unit. In addition,



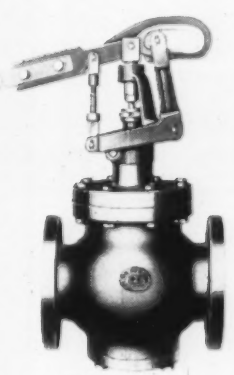
there are two instantaneous overcurrent units, one for each of two phases, whose function is to prevent tripping on fault currents less than their setting. These units are connected with coils in series, with the current windings of the starting units and their contacts in series with the main, tripping contacts. Each overcurrent unit has calibrated settings of 5, 7 and 10 amps. Operating time on phase-to-phase faults in proximity to the relay will range from 1 to 1½ cycles with corresponding currents of 20 to 10 amps. Relay is mounted in a 20" × 16" case with an 18" × 22" mounting flange. *General Electric Co., Schenectady, N. Y.*

Universal Microscopic and Microphotographic Equipment

New "Panphot" is said to represent the most universal microscope with photomicrographic camera. It is said that there is no method of microscopic observation which cannot be carried out with this instrument. Convenient arrangement for transition from visual observation to photomicrography fits it for routine laboratory work as well as for research work where photographic records under varied illumination conditions are required. Instrument is equipped with the new "Panopak" which serves for illumination of opaque objects, being a combination of a vertical illuminator and a darkfield condenser for reflected light and permitting quick change from vertical illumination (brightfield) to indirect illumination (darkfield). *E. Leitz, Inc., 60 E. 10th St., New York City.*

Fulcrum Mechanism for Control Valves

New "R-K No. 5 Fulcrum" was designed for two distinct purposes: (1) *Proportionality for automatic control.* This characteristic makes a valve equipped with this device suitable for operation by an automatic controller without hunting at low loads where a small movement near the seat may represent 100% change in flow. With the



new device, as fulcrum point is nearest valve stem when valve is on its seat, equal-increment of lever movement imparts proportionately shorter stem movement. (2) *Smooth "coming off seat."* This characteristic, desirable in operating single-seated valves, is an obvious consequence of lever ratio being greatest when valve is on seat. *Ruggles-Klingemann Mfg. Co., Salem, Mass.*

BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

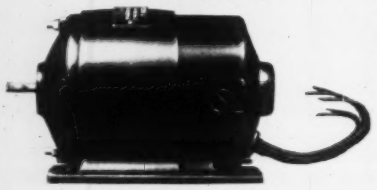
Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

New!



AUTOSYN
SELF-SYNCHRONIZING
MOTOR
TYPE I

Type I Autosyn motor is a reasonably priced self-synchronizing motor with superior performance characteristics. One transmitter may operate as many as six receivers. Practically any system of remote indication or control may be solved by the selection of the proper type of Autosyn Motors.

FEATURES

1. Conventional Motor mounting interchangeable with most standard self-synchronizing motor elements.
2. Approximate accuracy: Two degrees.
3. Maximum torque 14.8 inch ounces.
4. Safe continuous operating torque 5.6 inch ounces.
5. Brushes carry no current during synchronism.
6. Enclosed inertia dampener reduces oscillation to maximum of 3 seconds and is adjustable to suit.
7. Dimensions: 3⅝"x39/16"x 5¾".
8. Weight: 5 lbs., 12 oz.
9. Low current consumption and temperature rise characteristics.
10. Voltage range for accurate and safe operation, minus 20% to plus 10% normal rating.

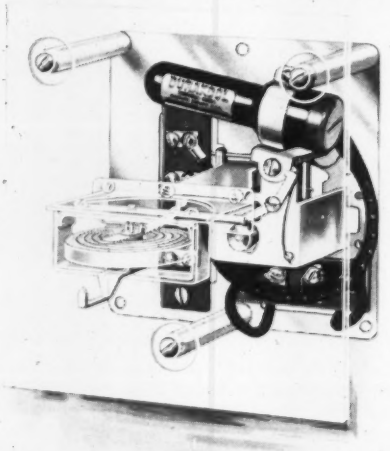
COMPLETE INFORMATION ON REQUEST.

BENDIX MARINE PRODUCTS CO., Inc.

Subsidiary of
Bendix Aviation Corporation
754 Lexington Avenue
Brooklyn, N. Y.

Universal Automatic-control Mercury-switch Mechanism

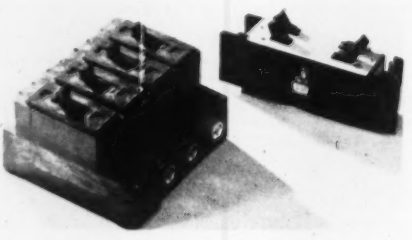
Unique in its interchangeability of primary measuring elements, the new "Durakool Condition Controller" comprises two main assemblies: (1) the rear portion, containing the mercury switch, periodic clamping device, driving motor, etc., and (2) the front plate, carrying any desired type or form of instrument responding to temperature, humidity, pressure, speed, flow-rate, illumination, etc. For example, the front-plate assembly shown in "phantom" effect in the illustration carries a condition-responsive element in the form of a spiral



which might be either a bi-metal thermometric element for temperature control or a hygroscopic element for humidity control. The essential requirement is that the condition-responsive element be of the pointer-deflecting form. Its pointer is not required to perform mechanical work, being periodically clamped as is the galvanometer pointer in a relay-type electrical recording instrument. The universal mechanism consists essentially of an electric-clock motor, a chopper-bar mechanism, a means of setting the control point from outside the case, and a "Durakool" mercury switch of any capacity up to 200 amps. *Durakool, Inc., 1010 No. Main St., Elkhart, Ind.*

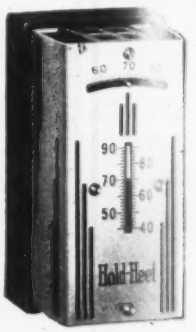
Automatic Load Center

A small automatic multi-breaker load center replaces the conventional fuse and switch combination for the protection and distribution of power in small buildings. Latest design has same interrupting ability but is much smaller than previous design (on left). Breaker capacities will be 15, 20, 25, 35, and eventually 50 amps single-pole with mechanical connection for 3-wire service when desired.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*, and *Square D Co., Detroit, Mich.*



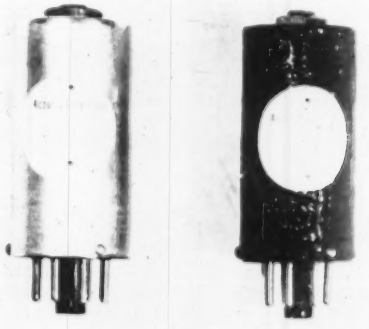
Room Thermostat

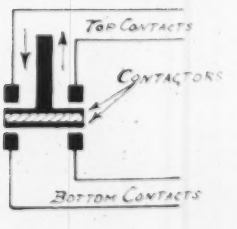
"Hold-Heet U3" has large openings at top and bottom of case for free circulation, together with bimetal element said to have unusually large radiating surface to mass, this combination giving quick response to changing temperatures. Accuracy guarantee is ± 1° in 15° range and differential < ± 0.5° F. Is of "heat anticipating" type, with magnetic snap action, for 2-wire or 3-wire circuits. Bakelite base is 3 7/16" long, 1 3/4" wide. *Russell Electric Co., 446 W. Huron St., Chicago, Ill.*



Solenoid Relay

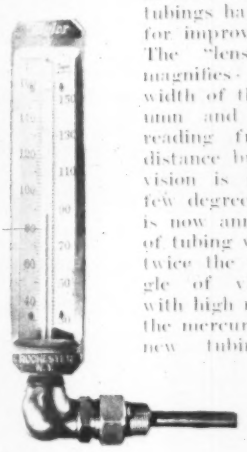
This new sensitive relay, designed especially for operation with a one-tube amplifier operated by photocells, etc., is in the form of a cylinder 1 3/16" dia. x 25/16" long; 3" overall including top screw and Octal base. Use of the Octal base eliminates soldering of wires and facilities insertion or removal from circuit. Relay operates by solenoid action and gravity; has no spring; has top adjustable pole piece and lock nut for adjusting to desired drop-out or pull-in value of energizing current; can be furnished with coils wound to practically any resistance value. Minimum practical coil wattage, for all coils, is 0.032 watt, but can be adjusted as low as 0.020 watt. Contact arrangement is single-pole double-throw, with double break on both throws and separate isolated contactors. Silver contacts and contactors will handle 100 watts on each circuit. Internal iron parts are of Swedish metal, cadmium plated. Relay can be opened for inspection by removing three small push pins at bottom of shell, and does not require unsoldering base pins. *Acousta-Lite Laboratories, 2930 S. Vermont Ave., Los Angeles, Calif.*





ustrial Thermometers with Easy-to-read Tubing

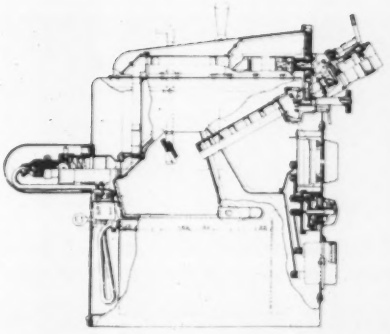
ercury-in-glass industrial thermom with small-bore cylindrical tubing been difficult to read except at range and under favorable illumination. Various forms of tubings have been devised for improving readability. The "lens-front" design magnifies the apparent width of the mercury column and hence permits reading from a greater distance but the angle of vision is narrowed to a few degrees of arc. There is now announced a form of tubing with "more than twice the accustomed angle of vision combined with high magnification of the mercury column." The new tubing, designated



"Binoc" (binocular vision), is characterized by a triple-lens front, the center lens not only magnifying the mercury column but said to be "so formed that the intensity of light concentrated upon the mercury column is greatly increased." The two outer lenses are said to "operate to gather much more light and focus it upon the contrasting background directly behind the mercury column." Still another characteristic is said to be the elimination of "empty-bore reflection" an effect which is said to make the empty portion of the bore of "conventional" lens tubing, when viewed from "even a slightly unfavorable angle," appear to contain mercury. The legibility of these new thermometers is further aided by bold black numerals and graduations on cream-tinted non-tarnishing scales. *Taylor Instrument Companies, Rochester, N. Y.*

Tyndallometer

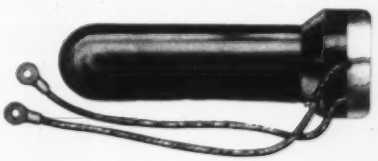
This newly-introduced instrument is a portable photometric equipment for determining dust content in air (as in mines and other places where the danger



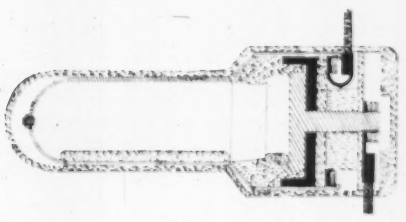
of silicosis exists) by measuring the intensity of the Tyndall beam a principle said to have been verified by extensive experiments. *E. Leitz, Inc., 60 E. 10th St., New York City.*

Calibrated Mercury Switches

Mercury switches of radically new design and construction, announced in 1-, 5-, 10-, 20-, 50- and 200-amp. capacities, are said to differ in operation from conventional mercury switches in that they each open and close at exactly specified angles these angles not only remaining the same throughout the life of the unit



but being independent of load or of speed of operation. It is claimed, therefore, that the new switches may be embodied in precision mechanism whose accuracy depends on the invariability of switch characteristics. After several years of accelerated breakdown and actual-service tests, makers assert also (1) that operating life of new device exceeds that of conventional-design switches, and (2) that the new heat-dissipation principle is the most efficient yet. Whence, the name "Durakool." Among other characteristics are the following: (1) Differential angle as specified, between 1° and 4°; (2) No "top" and "bottom" requiring careful adjustment into mounting, because operating surface extends all the way around inside; (3) No glass, no glass-sealed undersized inleads; (4) Metallic envelopes; (5) Special ceramic insulating parts containing no mineral oxides that would

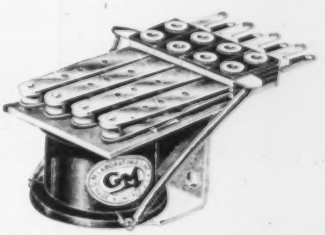


affect mercury; (6) Mercury purified by new method assuring invariable meniscus; (7) Vapor filling which will not leak away or be absorbed as would hydrogen, and which dissipates heat efficiently; (8) No radio interference. *Durakool, Inc., 1010 No. Main St., Elkhart, Ind.*

GM

RELAYS

ELECTROMAGNETIC



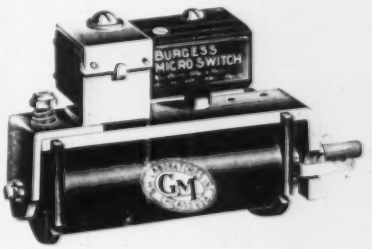
A.C. RELAYS, TYPE A

New, low cost, high quality relays of new improved design. 1 to 4 contact stacks which may be make, break or break-make.

4 sizes of contacts, 2 to 10 amps. Frequencies, 25 or 60 cycles Coil voltages, 2.5 to 125

D.C. RELAYS, TYPE E

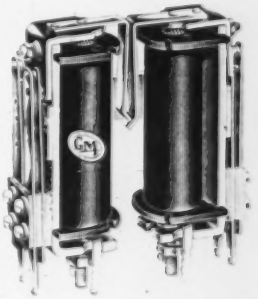
An excellent relay for accurate adjustment. Supplied in 25 ratings.



D.C. RELAY

WITH ONE or TWO BURGESS MICRO-SWITCHES

10 amp. capacity with make, break or break-made contacts.



TWIN-LATCH RELAY

A self-locking relay. Can be arranged for both electrical and mechanical inter-lock.

G-M LABORATORIES INC.

1732 Belmont Ave., Chicago, U.S.A.

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METALLIC BELLOWS *assemblies*

Hydron metallic bellows are used as control elements in temperature and pressure control devices, and for liquid or gas seals on compressors and pumps. They are formed from one-piece, thin wall, metal tubing of the highest grade, expressly developed for this purpose.

The bellows have exceptional life characteristics due to the automatic testing of the tube wall in our original patented hydraulic forming process, and to the freedom from rubbing of frictional tool engagement with the thin metal wall during the formative operation.

Increasing numbers of manufacturers find it more economical and more satisfactory to have us supply the complete bellows assemblies. We have the equipment and they are pleased with the results. Let us quote you on complete bellows assemblies for your products.

We are primarily manufacturers of bellows and bellows assemblies rather than completed devices incorporating same, with the obvious intent of avoiding any competitive situation between ourselves and our customers. We do, however, produce to our customers' specifications complete devices involving our bellows.

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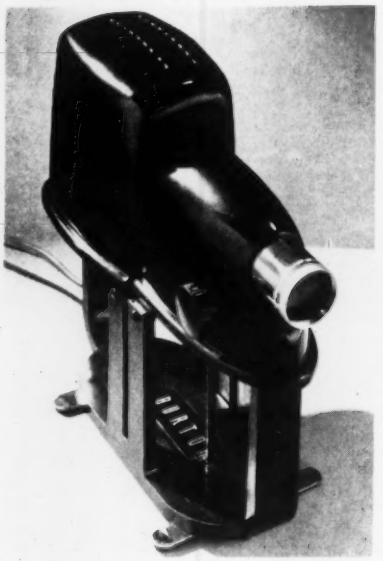
Riley Engineering Corp., 1481 14th St., Detroit
Franklin G. Slagel, 923 East 3rd St., Los Angeles
J. J. Shriver, 221 North La Salle St., Chicago



X-ray Film Projector

This new projector measures 10" overall, and with the screen can be used in a 2-ft. space. It has an achromatic lens with geared focusing device which brings out minute detail on the film in greatly magnified form. It is said to take "any size film." *Burton Mfg. Co., 607 N. Michigan Ave., Chicago, Ill.*

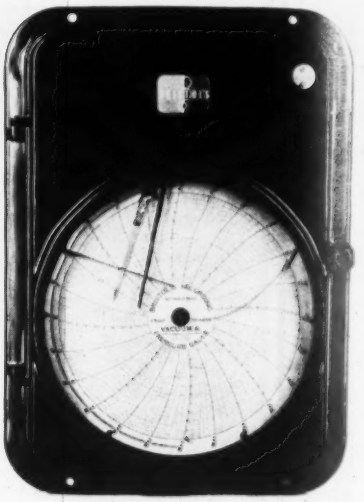
Car Battery Tester

New model "E-142 Battery Analyzer" determines the percent of useful plate life remaining. A chart, mounted on the panel, explains the amount of remaining plate life as indicated on the etched dial,

thus makes remaining battery life apparent to the car owner. Other features are a moving-coil indicator (with balance line), chrome-plated etched plates, adjustment to battery temperature, adjustment for plates per cell, individual cell testing facilities, etc.—*Allen Electric and Equipment Company, 2101-2117 North Pitcher Street, Kalamazoo, Michigan.*

Low-range Pressure Recorders and Controllers

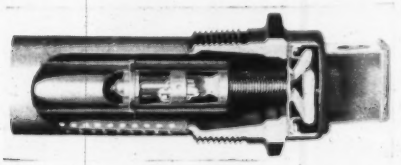
Equipped with liquid-sealed bell[illegible] measuring elements, these new additions to maker's line of pressure instruments are available for pressure or draft



ranges, minimum 0 to 0.2 inches of water and maximum 0 to 2.0 inches of water. Controllers employ "Free-Vane" design of air pilot (see *Instruments*, Jan. 1932, page 9) and are equipped with "Amplset" sensitivity adjustment (see *Instruments*, June 1936, page 156) for adapting throttling range to application big. Designated as "Model D 40 M," these instruments are housed in maker's 12" case, for wall and flush panel mounting. —*The Bristol Co., Waterbury, Conn.*

Float Operated Switch

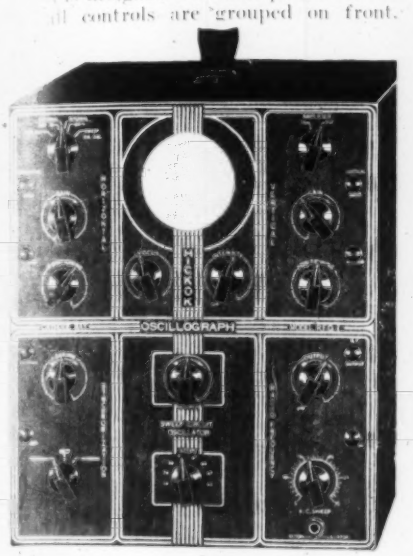
Consists of a mercury switch inside float which is attached to the head by means of a flexible metallic bellows. As the float switch moves through its arc, the mercury switch makes and breaks contact. Unit shown can be screwed in a horizontal position directly into a tank or vat, at any desired height. When level reaches a height that will move the float, mercury switch makes contact to sound an alarm, flash a light, or to start a motor-operated pump or other electrical device. This particular unit is used as a low water cut-off switch to stop oil burner or stoker when boiler water level falls to danger point. A device of similar design is equipped with a three-wire switch so that it makes one circuit and breaks another when the float is moved through its arc by rising or falling liquid level. Several models: In addition



to type shown it is also built with a float chamber with tappings for equalizing pipe connections to the tank or vessel; also made for installation in the gage glass tappings of a tank or boiler. —*McDannell & Miller, Wrigley Bldg., Chicago, Ill.*

Cathode-ray Oscillograph

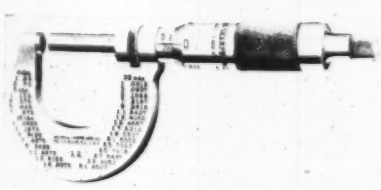
New "Model RFO-1" has a 3" No. tube and a built-in frequency modulator, is designed with unit panels whereon all controls are grouped on front.



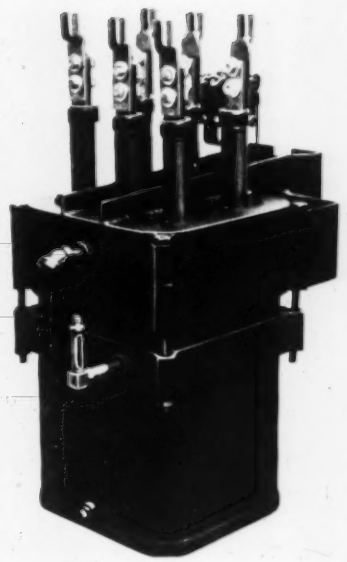
Self-contained power supply operates on 110-volt, 50- to 60-cycle a.c. Upper left and right panels are for vertical and horizontal deflection-plate controls respectively; each has gain and positioning knobs and a 4-point switch for connecting amplifying 6C6 tube, 30 kc. sinusoidal trace, etc. Tube panel has focus control knob and intensity control knob which also serves to disconnect oscillograph. Lower left panel, for synchronizing, permits selecting sub-multiples of 60-cycle saw-tooth sweep or to lock horizontal sweep with any frequency applied to vertical plates. Lower center panel contains step and vernier control of sweep circuit oscillator: eight steps, with overlapping between, to permit locking in any frequency between 15 and 25,000 cycles. R-f. panel (lower right) contains output control which permits varying from 2 microvolts to 3 volts, and kilocycle sweep control for width of frequency modulation of r-f. oscillator. This section may also be used as an electronic frequency modulator. A calibrated screen is supplied with this oscillograph. Dimensions 11"×13"×15¼" deep.—*The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*

Micrometer Calipers

New design of 1" micrometer calipers combines utility of "C" frame with advantages of maker's old "No. 12" and "No. 13" design. Narrow (1 1/32") anvil



end permits measuring deep in slots. Frame is said to be proportioned for strength and rigidity. Available in 0.001" or in 0.0001", with or without ratchet stop, with or without tungsten carbide facing on spindle and anvil.—*Brown & Sharpe Mfg. Co., Providence, R. I.*



Oil Circuit Breakers

Re-designed "Turbolator" indoor types of oil circuit breakers are said to surpass requirements of latest standards. Principle of arc extinction effects quick quenching of arc, reducing arc length and tank pressure, and minimizing contact burning. Available in 600 to 2000 amps., 7500 and 15,000 volts, in interrupting ratings from 10,000 to 250,000 kva. Illustration shows 50,000 kva, 600-amp., oil-tight, common frame breaker with bushings reversed from makers' usual arrangement. Among construction features are special alloy steel heads to reduce heating, Bakelite insulators with special grounding shields to prevent corona discharge, self-lubricating balanced mechanisms.—*Roller-Smith Co., 2132 Woolworth Bldg., New York City.*

Incandescent Lamp Blueprinter

A 24" × 36" model has been added to the line of Angstrom lamp Blueprinters. This one is double the size of previous models. Essential features of the

older model are retained, including the use of incandescent lamps as a light source and elimination of the belt feed by the flat bed printing surface. A heavy-duty timing switch has been developed for automatically breaking the heavier current. Forced ventilation prevents tendency to overheat. Economy of operation is claimed for the new model with a cost for prints approximating $0.013/ft².—*Milligan & Wright Co., 1215 West Third St., Cleveland, Ohio.*

Royal Berlin Porcelain

for

HIGH TEMPERATURE WORK

COMBUSTION TUBES AND TUBING

K MASS

Withstand temperatures up to 1700° C. without pressure, and up to 1600° C. in a vacuum. Impervious to liquids and gases.

Catalogue RB 250 on request

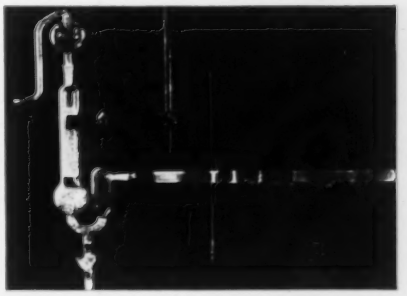
K-82 MASS

The latest development of porcelain for high temperature testing in a vacuum. Combustion tubes of this mass are used in the "burning out process" of certain metals used in the manufacture of vacuum tubes. Withstands temperatures up to 1700 ° C.

Further information on request.

●

Jena Grote Apparatus



for the determination of

Sulphur and Halogens in Combustible Substances, including Mineral Oils, Kerosene and Bituminous Products.

Rapid, Accurate and Reproducible.

Further details on request.

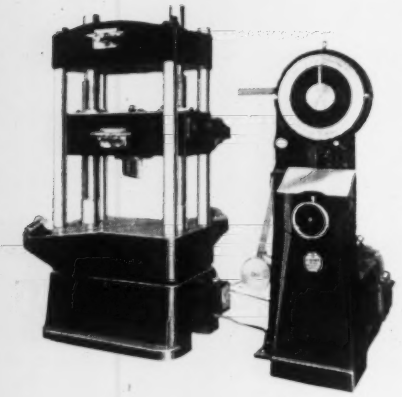
U. S. Distributors

FISH-SCHURMAN CORP.

230 EAST 45th STREET

NEW YORK CITY

ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS



UNIFORMITY

The dead-weight automatic indicating system in the Riehle Precision Hydraulic Testing Machine has no springs, no levers. True, uniform results are positively assured. The diameters of the main and measuring plungers will not change as there is no friction in any parts of the weighing unit or those connected to it.

No recalibrations are necessary in the Riehle Precision Hydraulic Testing Machine.

Write us—ask us to send you bulletin describing this and other Riehle Testing Machines.

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AMERICAN MACHINE AND METALS MANUFACTURING CORP.

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100 Sixth Ave., New York City

FACTORIES
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RIEHLE DIVISION

Plugs and Receptacles

New 6 pole multiple circuit plugs and receptacles, rated 10 amps., 250 volts are available for instrument circuits, thermocouples, remote control circuits, etc. Housings are heavy gage drawn steel, cadmium plated. Contacts (especially the male contacts) are protected by the Bakelite insulation and the steel housings. Plugs can be inserted in only one position. Male and female contacts are self-aligning as they are arranged to float in the insulation. Bayonet locking

device prevents accidental separation as a twist and a pull is required to move the plug. Rubber packed cord clamp relieves strain from the wires at the contact terminals, also excludes dirt and moisture from the terminal connections. These plugs and receptacles are available in two forms of interior assemblies, arranged so that when in use it is impossible for the operator to touch live contacts. *Pyle-National Co., 1334-58 No. Kostner Ave., Chicago, Ill.*

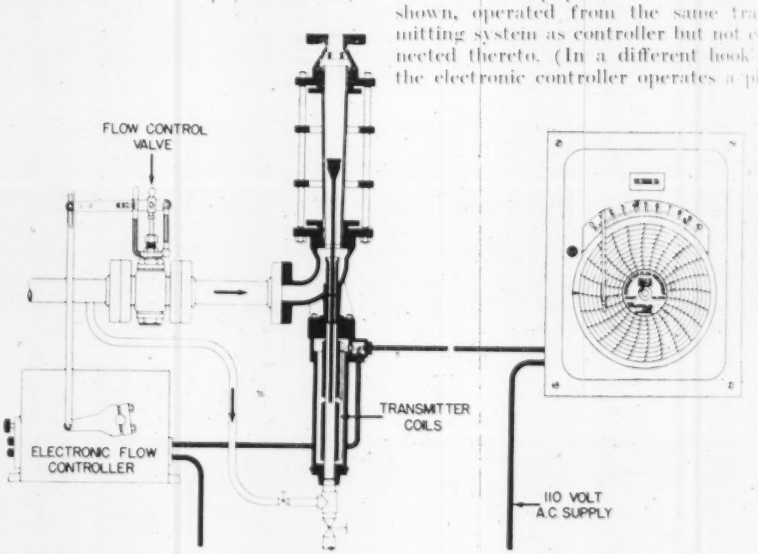
Measuring Microscope

This newly-introduced instrument serves for the control of thread [illegible] and angle, profiles of working [illegible],

etc. It may likewise be used for accurate measurements of the distances between drill holes in jig plates and other precision measurements in the workshop. *E. Leitz, Inc., 60 E. 10th St., New York City.*

Flow Control Systems

Several new systems for automatic control of rate of flow of liquids, vapors and gases in piping systems are announced. In each, the primary flow-rate measuring element is a "Rotameter" (see *Instruments*, Dec. 1933, pages 222-225). Illustration shows a typical hook-up with the flow controller operating the control valve directly through mechanical linkage to the drive motor which is housed in the same case as the rest of the control equipment. A recorder is shown, operated from the same transmitting system as controller but not connected thereto. (In a different hook-up, the electronic controller operates a pilot



These new systems differ from the one described in our April 1935 issue, page 107, in that they embody electronic power tubes for energizing the valve-operating devices. They consist of (1) a standard Rotameter with a magnetic armature rod attached by means of a non-magnetic extension to the float in the metering tube, (2) a divided transmitter coil attached to the Rotameter (3) the control unit itself containing a divided receiving induction coil, grid controlled electronic tubes and drive motor energized by the tubes and (4) the flow control valve located in the same line as the Rotameter and driven by the motor. valve in an air line to a diaphragm valve in the main line. This arrangement is used where it is desired to keep motors and other electric equipment away from the process flow lines.) A "trend analyzing" system causes the movements made by the control valve to be rapid if the deviation from the desired control point is great, and slower as the control point is approached. The controller is equipped with adjustments for sensitivity so it can be "tuned in" to process requirements. Overshooting and hunting are said to be eliminated. *Schutte & Koerting Co., 12th & Thompson Sts., Philadelphia, Pa.*

Development and Principles of the Gyropilot

By PRESTON R. BASSETT
Vice-president, Chief Engineer
Sperry Gyroscope Company
Brooklyn, New York

In 1913, aviation and the Sperry Gyroscope Company were young and unrelated, but Elmer Sperry's son, Lawrence, was interested in flying. His shop talks with his father brought out the need of more stability in those early airplanes and Elmer Sperry, eagerly looking for new uses for the gyro, saw the opportunity. The two enthusiastic Sperrys combined their hobbies of gyros and flying and made an ingenious contrivance which they took to Paris in 1914. Soon the newspapers were carrying stories of young Lawrence flying his airplane without touching the controls. He even stood up in his plane and his mechanic climbed out on the wing, while the Airplane Stabilizer, as the Gyropilot was called, flew the ship. (See Figs. 1 and 2.) These performances won the *Grand Prix* at the Paris air meet that year, and the Sperry gyro obtained its first international

Fig. 1

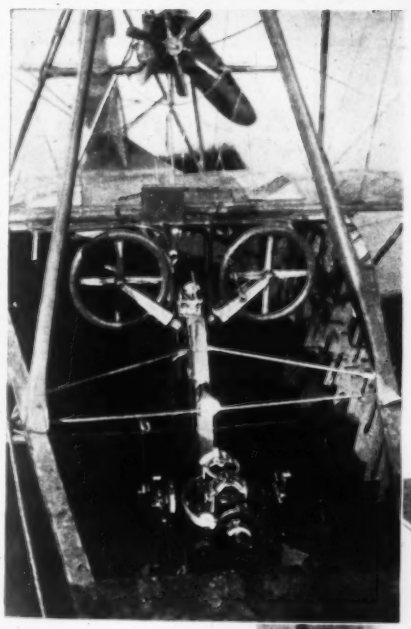


Fig. 2 — 1914 "Stabilizer" with which Lawrence Sperry won Grand Prix. Note cockpit mounting.

fame, but the idea was ahead of its time. Airplanes were small; weight was at a premium, and during the World War the more practical approach to stabilization was found in designing airplanes with more inherent stability.

In the lean years following the war, aviation's problem was not so much to design new material as to develop peace-time uses for the airplane. The air mail laid the foundations of air transport. Then, a vast and efficient ground organization made it possible for passengers as well as mail to be carried. The advent of the large passenger-carrying airplane created new uses for the automatic pilot: the human pilot's increased responsibilities called for mechanical aid to relieve him of routine physical duties, and weight was no longer a barrier. The 1926 model (Fig. 3) weighed about 160 pounds, but it was small enough to be completely contained beneath the pilot's seat. Experience with this unit in turn pointed the way toward the next engineering steps. Our 1930 model (Fig. 4) consisted of two gyroscopes—a horizon gyro and a directional gyro—both driven elec-

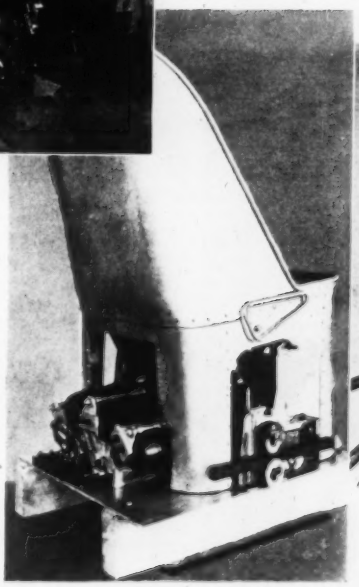


Fig. 3 — 1926 First Gyropilot installed in a large transport plane (Ford Trimotor). Note location under pilot's seat.

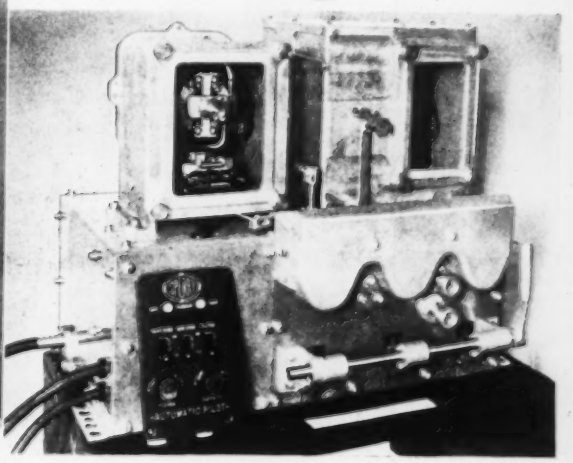


Fig. 4. The 1930 Gyropilot—greatly reduced in weight but still too cumbersome to be mounted on instrument board.

trically and having electric trolleys and contact pick-offs. Solenoid-operated clutches were commanded by the trolley and contact circuits. The servo power was obtained by a wind-driven fan which imparted constant rotation to the power shaft against which the solenoid clutches operated. This unit was a step far in advance of the previous airplane pilot, and we were proud of the achievement of getting the weight down to "less than the weight of a man" about 120 lbs. The unit, however, was of such dimensions that it could not be mounted in front of the pilot. (On our first installations we had had to locate the Gyropilot under the pilot's seat, behind it, or even in the baggage compartment behind the cockpit.) Meanwhile, two separate blind flying instruments, the Directional Gyro and the Gyro Horizon, had successfully been developed, and their air-driven gyro elements were now incorporated in the Gyropilot.

Two further improvements were necessary before the Gyropilot could be considered practical. First, the motion of the control surfaces had to be made smooth instead of jerky as was the case with the clutching system. Second, it was desirable to have the control units in front of the pilot where he could see them and, especially, where he could reach them to make the necessary adjustments. The two gyros could then be used either as blind flying instruments or as automatic control units. The first equipment which met these requirements (weight 60 lbs., smooth and sensitive hydraulic controls) was finished just in time to be installed in the *Winnie Mae*. Wiley Post and Harold Gatty had completed their record breaking flight around the world, but Post, not content, wanted to beat his other record by flying alone, with only the Gyropilot for relief. On July 15, 1933, he started alone on his second flight around the world. 186 hours after taking off from Floyd Bennett Field, he landed there again, unfatigued and with high praise for his Sperry Pilot (Fig. 5). The Gyropilot had arrived! Since then installations of the new type have proceeded until now there are more than 200 in use. Over a million miles a month are flown automatically with their aid.

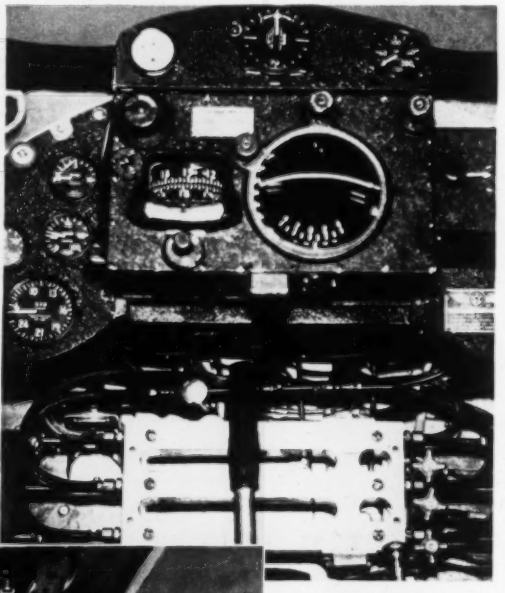


Fig. 5 — 1933 First appearance on instrument panel. Gyropilot installed in the Winnie Mae.

Fig. 6 — 1936 Typical air transport installation (Sikorsky S-42). Gyropilot unit in upper center of instrument board.

PRINCIPLES OF OPERATION

A solid body in space has six degrees of freedom, three of translation and three of rotation. An airplane in flight is satisfactorily restrained with respect to translational displacements but possesses all three degrees of angular freedom, so that stabilized flight requires control of its rotation about three axes. For this purpose an airplane has three controls: the rudder for direction, the elevator for climb and the ailerons for bank. The Gyropilot consists therefore of three control sys-

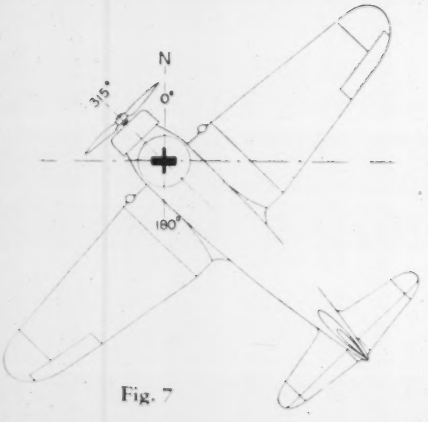


Fig. 7

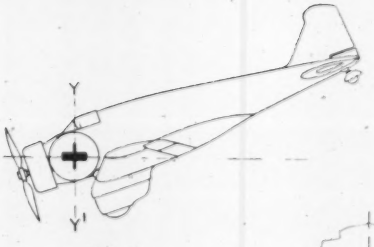


Fig. 8

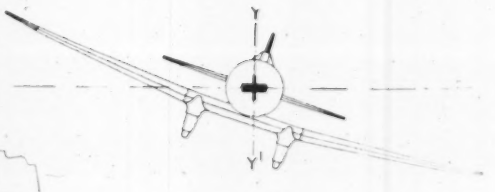


Fig. 9

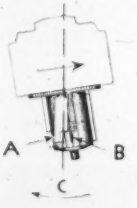


Fig. 10

one, actuated by the Directional Gyro, con- the rudder (see Fig. 7); the second is actuated the Bank and Climb Gyro and controls the ele- ; the third, which is also actuated by the and Climb Gyro, controls the movements of the ons.

glance at Figs. 7, 8 and 9 will show that two gyro elements can provide the three essential indica- In the Sperry Gyropilot one such element constitutes the Directional Gyro and the other constitutes the combination instrument known as the Gyro-Horizon.

The *Directional Gyro* is a free gyro- scope to which a compass card is at- tached. It rotates with its axis horizontal. By means of a knob it may be set to the same course as the magnetic compass (with which it must be periodically com- pared, and reset if necessary). In Fig. 7 it has been set to North and its card reads 315°, the airplane heading ex- actly NW.

The *Gyro - Horizon* (Bank and Climb gyro) rotates with its axis Y-Y′ vertical. It simulates the natural horizon and indi- cates to the pilot the an- gular positions of the air- plane's longitudinal and lateral axes with respect to a horizontal plane. Thus in Fig. 8 it indi- cates to the pilot the movement of the airplane in a glide; in Fig. 9 it in- dicates to the pilot the movement of the airplane in a bank. This gyro must absolutely main- tain its vertical-axis posi- tion, and it is held to it at all times within a frac- tion of a degree, by the arrangement illustrated schematically in Fig. 10. Four pendulous vanes (one of which is shown at A) are added to the under- side of the gyro housing. Each one of these vanes parti- ally covers one of the four air ports, B, that exhaust the air from the turbine gyro compartment. When the gyro deviates from its upright position, gravity holds the vanes vertical and one vane will close one port and the opposite vane will completely open its port. The force of the air coming from this open port will move the gyro, in the direction C, back to its normal position. The corrective movement, C, at right angles to the air force, is "precession," characteristic of all gyroscopes.

Both these gyros are in effect miniature air turbines, driven by air suction. The same pneumatic system which furnishes the power to drive them constitutes also three sets of 'nerve systems" commanding the three "muscles" which operate the directional, longitudinal and lateral controls. The changes in attitude which are visually in- dicated to the human pilot on the dials of the Gyropilot cause the controls for automatic flying to be actuated through three systems of air pick-offs, each forming the first stage of a "nerve system." One set of air pick-offs is embodied in the Directional Gyro; two are connected with the Bank and Climb Gyro. To illustrate the action of the Gyropilot, only the aileron control will be dis- cussed. The rudder and elevator controls are operated automatically in a similar manner.

Fig. 11 is a schematic diagram of the aileron control. The air pick-offs, X-X′, have been drawn at an exagger- ated angle (corresponding to an excessive degree of bank) to show that in a bank the air port D′ in pick-off X′ is shut off and air port D in pick-off X is opened, so that air can- not flow through D′ but can flow through D. The flow is induced by the same suction pump which drives the turbine-like bank and climb gyro. When the airplane is in level flight, with its lat- eral axis horizontal, both pick-off ports are open equally; but when the airplane tends to roll, one port starts to close, immediately creating a differential pressure which moves diaphragm E of the air relay. In Fig. 11 it will be seen that the air which enters the right hand side of the air relay di a ph r a gm chamber (from the atmosphere through the screened air intake) is drawn through the tubing and through D to M, while the left-hand side of the diaphragm chamber, having its con- necting tubing dead-end- ed at D′, is at atmos- pheric pressure. Conse- quently, diaphragm E is shown moved to the right.

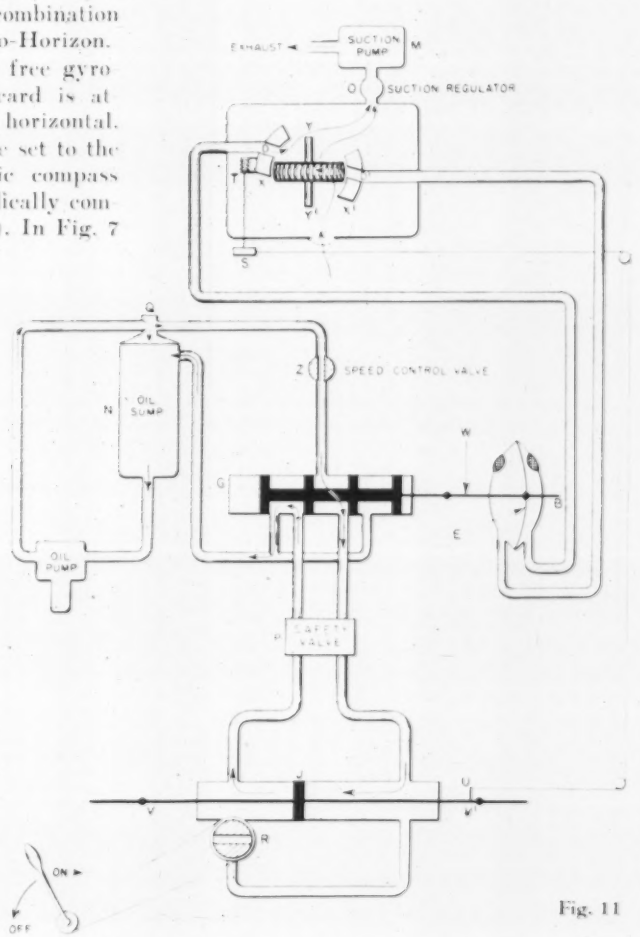


Fig. 11

To most readers of *Instruments* this pneumatic "nerve system" will not seem unfamiliar, resem- bling some industrial and laboratory air operated auto- matic regulators. The Gyropilot's three "muscles"—hy- draulic servo systems using oil as the operating fluid— will likewise seem to be counterparts of industrial hydraulic controllers—even to their individual follow-up systems.

The air relay is connected by means of piston rod W to pilot oil valve G, a balanced valve of standard design, which operates the hydraulic servo unit positively, by admitting oil to one side or the other of piston J. When the airplane is in level flight and diaphragm E conse- quently in mid-position, pilot oil valve G is likewise in neutral and no corrective action is taken by the servo unit. In Fig. 11 a corrective action is shown taking place, oil under pressure moving piston J to the left and oil being drawn from the left of the servo cylinder to the oil sump N. Piston rod V-V′ being connected to the aileron control cables, the ailerons are operated to re- store the lateral angle to zero.

While a small amount of hunting is permissible in many industrial applications of automatic control, the least noticeable trace of it in the performance of a Gyro

pilot would prejudice passengers and pilots against automatic flight. Over-control is prevented by the follow-up system shown in Fig. 11. A cable connected to the servo piston rod at U runs up to the follow-up pulley S on the gyro box. This pulley controls gear T which is connected to a gear on air pick-off X. As soon as piston J starts to move to the left, the gear moves X down and X′ up, thereby retarding the further movement of the aileron. The Gyropilot's mode of control is much like the behavior of a good motorist who, when rounding a corner, starts returning the wheel slowly until his car is straightened out on the new course. Control may be adjusted with nicety by means of the speed control valves, Z, which regulate the speed of oil flow to the pistons.

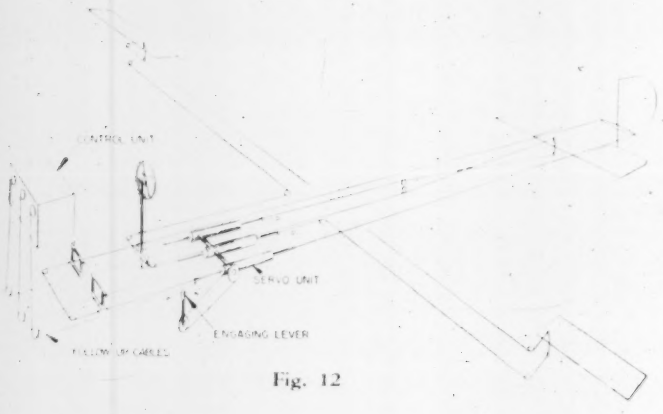


Fig. 12

Safety valves, P, permit the human pilot to overpower the Gyropilot while operating.

Fig. 11 shows also some parts of the Gyropilot which are common to its three automatic-control systems: When the human pilot flies the airplane manually for take-offs or landings, valve R is opened, permitting the oil to circulate in either direction through the by-pass around piston J in all three servo systems. The suction regulator, O, keeps the vacuum at 4″ Hg. regardless of the speed of the suction pump, which varies with the speed of the motor. The oil sump, N, carries the reserve oil, and Q regulates the oil pressure from the pump.

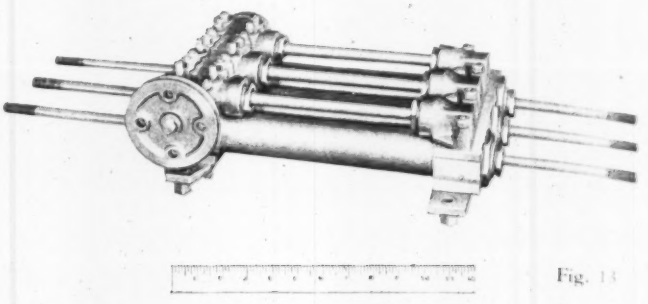


Fig. 13

The arrangement of the cable connections of all three automatic-control systems of a typical Gyropilot installation is shown schematically in Fig. 12 which brings out in particular how each servo piston rod forms a part of each main control cable. Fig. 13 shows the three-cylinder servo unit, which weighs only 9 lbs.

1850—Edward Weston—1936

Dr. Edward Weston, founder and chairman of the Weston Electrical Instrument Corp., died, August 20, at his home in Montclair, N. J.

Dr. Weston was born May 9, 1850, at Brynn Castle, Shropshire, England. His early education was gained in Wolverhampton, Staffordshire, a town of mining and metallurgical interests, and the young man soon began experiments with a view to understanding the phenomena of dynamic electricity.

Dr. Weston

At 16, young Weston delivered a public lecture on the subject. His parents desired him to study medicine and dentistry; his refusal made it necessary for him to strike out for himself, which he did, landing at New York on his twentieth birthday in 1870.

His first work here was with a company manufacturing photographic chemicals. In its research laboratory he perfected the manufacture of collodions. A year later he improved the crude process then used in nickel plating. To him is conceded in large part credit for the fundamental process of the vast plating industry of today.

His next experiments resulted in the construction of the first electro-plating dynamo in 1872. Field regulation of a dynamo, due to his research, is still the method in universal use. The Weston dynamo entirely replaced the primary battery as a source of current for all metallurgical work, revolutionizing the industry. Dr. Weston devised the laminated core which increased dynamo efficiency from less than 40 percent to over 90 percent. He introduced slots for embedding the armature conductors, low-resistance symmetrical armature windings, low armature reaction, ventilated cores, short and compact magnets, all tending to secure high efficiency and good regulation.

The Weston Dynamo Electric Machine Co., incorporated in 1877, became the Weston Electric Light Co. in 1879, and two years later was consolidated with the United States Electric Light Co., with Weston as chief electrician. He was the first to work out the commercial manufacture of arc light carbons. In 1878 he patented arc light carbons chemically treated for imparting a metal vapor. The flaming arc, embodying his inventions, has come into general use. His improvements of the incandescent lamp were of even greater importance. In working them out he built in 1876 the first electric furnace, perfected the carbon filament, and made the incandescent lamp a commercial possibility. He also devised greatly improved mercury pumps for exhausting air from bulbs and developed an accurate method of measuring a lamp's capacity.

The Weston cadmium standard cell was adopted as the international standard of electro motive force.

In 1885, Dr. Weston perfected an entirely automatic regulator and indicator for central stations.

In 1886 he built an experimental laboratory for the express purpose of developing convenient electrical measuring instruments, and the Weston Electrical Instrument Corp. was formed in 1888. With accuracy in view, he invented many special tools. One is a drill so small that the operator is obliged to use a microscope.

In 1888 he brought out the first line of direct-reading electrical instruments. To his genius are due also the modern external shunt and the alloys "Constantan" and "Manganin."

It is impossible to enumerate all of Dr. Weston's inventions. Early in his career he failed to appreciate the value of his discoveries and neglected to patent many of them. Of patents he held a half thousand or so, just how many is a guess.

So many honors were showered upon him by governments, societies, universities, etc., that space limitations prevent an attempt at listing them.

(Condensed from *Newark Evening News*)

nterpretation of Oscillograms

...th part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1935 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

GENERAL CONSIDERATIONS

For the convenient solution of actual problems met with in practice, the usefulness of a cathode-ray oscillograph depends largely on the ease with which the oscillograms can be interpreted. In many cases a photograph or other permanent record of the oscillogram is not required, a visual inspection bringing out all essential data. Acquaintance with oscillograms, readily gained through study of representative diagrams, will permit the selection of some system of connections that will disclose the desired information with the least effort in interpretation. The purpose of this article is to present the groundwork—an introduction to the study of diagrams and to the schemes of connections for obtaining them.

In industrial production tests (as of vacuum tubes), there is required a continuous succession of test readings, usually of electrical instruments. Much time is inevitably lost waiting for pointers to come to rest. A cathode-ray deflects instantly and in this regard makes an ideal inspection device. Moreover, the illuminated indication makes possible the use of opaque screens to delimit the tolerances; and final automatization may be achieved by using photoelectric tubes or cells to do the "inspecting" and to operate signals or to actuate relays for the control of production processes. In such modern industrial applications, as well as in laboratory applications, the cathode-ray tube does its best when the user knows in advance what sort of diagram will best serve the particular purpose—exactly as in the use of ordinary instruments, where the experienced user specifies the form of "scale law" which will best serve his purpose. The difference is that with a cathode-ray tube the user himself can arrange for obtaining the particular kind of oscillograms which will best serve his purpose today, and he can make a drastic change tomorrow.

There are several possible schemes of classification of oscillograms, but for present purposes two main divisions will suffice: Oscillograms in which the deflection in one direction is dependent upon TIME will be considered as Class I, while in Class II fall those figures in which the deflections along both axes depend upon separate and distinct functions of given conditions.

Class I figures (insofar as interpretation is concerned) are not unlike the oscillograms obtained with the usual mirror oscillograph of the Blondel or other types. In the second class we have hysteresis curves; modulation diagrams; characteristic curves of transformers, tubes, amplifiers and other devices; phase and power measurements; resonance curves, etc.

To obtain Class I figures, a known timing wave is generally applied to produce a deflection in one direction, or (less frequently) the moving spot is viewed in a revolving mirror, or recorded on photographic paper or film. In any case the oscillograms are straightforward and require no special technique in analysis. The time scale is usually (but not necessarily) either linear or sinusoidal. Conditions also arise where the time base has a logarithmic increment—as in studies involving sound pressures or the frequency spectrum. "Time" need not always be reckoned in terms of the standard second, however, and in some tests it is found more convenient to use an extremely flexible "unit" of time for the horizontal deflection (the abscissa). Examples occur in the studies of certain mechanical processes in terms of cycles of operation; also in the study of heart conditions where the time base is the interval between successive beats.

It is in Class II that the greatest variety of useful applications fall. The characteristic feature of the cathode-ray type of oscillograph, namely, that of having two degrees of freedom, permits a great many electrical and non-electrical simultaneous measurements to be made in the form of controllable Class II diagrams. The simplification which the commercially available tubes have recently undergone in the matter of accuracy adjustments, the use of lower anode potentials, and the increased brilliance are proving incentives to the adoption of this device for many testing applications. The equipment requirements usually involve the selection of the proper pickup or conversion units, as described in the May and June 1936 articles.

Curiously, many of the possible applications in this category are not widely appreciated, doubtless due to the widespread use of commercial oscillographs designed for the convenient employment of linear timing waves, so that the arrangements that do not use such a time base are not considered. It also happens that some of the functional "cyclograms" belonging to Class II are relatively difficult to analyze. It will be the purpose of the next few articles to cover in greater detail many of these applications in several fields of testing and research.

The main problem is usually to select the test circuit that will disclose the desired information directly without unnecessary mathematical analysis, and one that is simple to set up and control. The greatest disadvantage in using a cathode-ray tube is the absence of a stable calibration, if either the supply voltage varies or the anode voltage changes for other reasons.

The cathode-ray tube indicates the instantaneous voltage across the test points connected, and therefore the peak voltage. The direct potential required for a similar deflection can be easily measured with a voltmeter. This provides a simple check on the sensitivity unless, of course, a vacuum-tube amplifier stage permanently connected to the deflection plates is used.

In test setups hereinafter described, the cathode-anode supply circuits will be ignored, unless they play a definite part in the test, and it will be assumed that the tube and its associated power supply are correctly functioning. In the circuit diagrams the deflection plates only will be shown, using the usual symbols.

In most cases the anode terminal of the cathode ray tube will be found connected to one plate of one or both pairs of deflection plates, and it is usually desirable to ground this common terminal either directly or through a "leak" resistance of one-half megohm or lower. This ground must be considered when any external circuits are connected to the deflection plates.

An oscillograph lends itself admirably to the comparison of frequencies, as for instance the calibration of radio or audio oscillators and frequency meters against a standard. In such measurement either the frequency ratio is measured, or the frequency difference, or else a combination of both.

Definite patterns, instantly recognized after little practice, always result when two frequencies having a common factor are applied to the deflection plates. As long as the frequency ratio remains steady the pattern on the screen does not change its appearance.

At times, however, the pattern itself blends from one aspect into another, following a definite sequence and

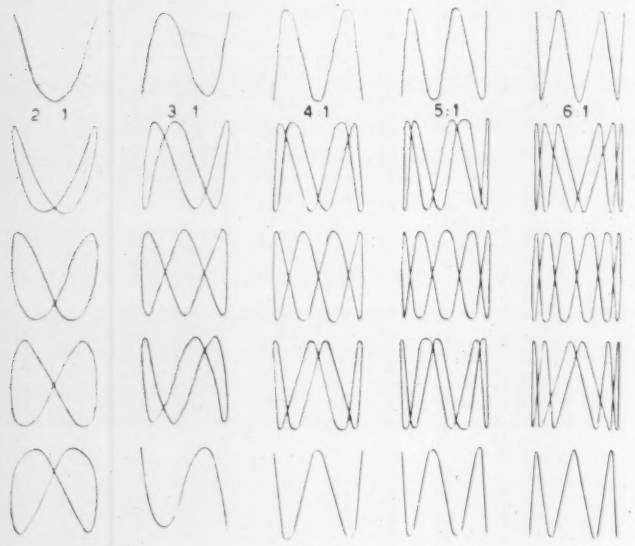


Fig. 1

returning to its original aspect again and again at relatively long intervals of time. (See Fig. 11, Feb. 1936 article.) Each series of such changes represents the gain or loss of one cycle by the lower frequency over the equivalent sub-multiple of the higher frequency.

Such a study of the frequency relations between an unknown wave and a standard thus resolves itself into two problems: that of noting the type of diagram which appears momentarily at definite intervals, and then determining the rapidity of such recurrences.

Illustrating the application of the above solution, a number of common frequency ratios are illustrated in Fig. 1, from which several rules can be formulated that will enable the identification of more complicated figures. In practice the figure may be found to be rotated 90° or 180° or some intermediate amount. Should this cause confusion at first, hold the page at an angle, or rotate the cathode-ray tube about its axis, or else reverse the connections to the deflection plates. (A rotation of 90° is of course the same as interchanging the connections to the deflection plates.)

In order to simplify discussions of diagrams, the timing base frequency, assumed to be the standard, will be represented by the letter *n* while the unknown wave will be represented by *f*.

[1]Rasmussen. Frequency Measurements with a Cathode-ray Tube. *Journal A.I.E.E.*, Vol. 46, 1927, pages 342.

[2]Wood. A method of Frequency Measurement with the Cathode-ray Oscillograph. *Review of Scientific Instruments*, Vol. 3, 1932, pages 378-383.

[3]Hazen & Kenyon. Primary Radio-frequency Standardization with a Cathode-ray Tube. *Scientific Paper S489*, 1924, National Bureau of Standards.

[4]Kemp. Theory of Alternating Current Wave Forms. Instruments Publishing Co., Pittsburgh, 1935.

The most frequent setting is where several cycles of the wave under test occur during one cycle of the timing wave. A few simple ratios are given in Fig. 1. The aspect of the diagram on the screen will depend upon the phase relation between the two frequencies, so that several of the possibilities for each frequency are shown in the vertical columns. Starting in each case from a single line, the figure gradually blends through a series of multi-looped forms until it again reaches its original shape. With the exception of Column 1 with the 2:1 ratio, the series represents a shift of 180 degrees. During the interval representing the next half-cycle shift, the series goes back to the original aspect.

When the location of a point on a plane is controlled by periodic forces bearing some definite relation to each other, a "Lissajou" figure[4] results. Such figures were originally produced by the application of two sinusoidal waves normal to each other, but the term has come to include figures produced by non-sinusoidal waves as well. In certain cases where the vertical and horizontal deflections are so related that the area represents "energy," the diagram has been called a cyclogram.

(In Fig. 11, Feb. 1936 article, the ratio of frequencies is unity, but phase differences of 0°, 30°, 60°, 90° and 180° are shown by the diagrams in Column A. Note that the diagrams for 0° and 180° are sloping straight lines, and that intermediate diagrams are ellipses.)

In the first column of Fig. 1 the frequency ratio is 2:1 with phase differences of 0°, 30°, 60°, 90° and 120° respectively. The frequency ratios of 3:1, 4:1, 5:1 and 6:1 are reproduced under the phase conditions of 0°, 45°, 90°, 135° and 180°. Rules will be discussed later for determining the actual phase difference from measurements on curves of this nature.

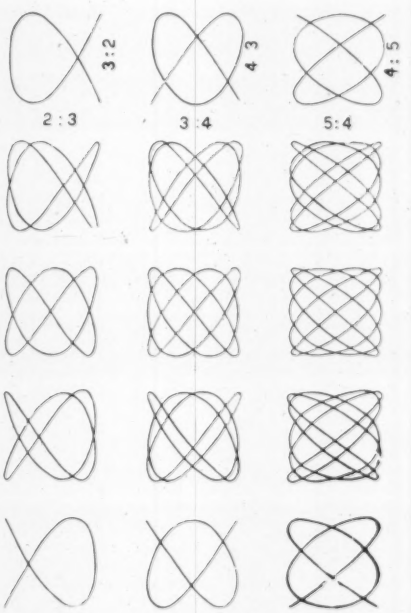


Fig. 2

In case the frequency ratio is not an integral such as 2:3, more complicated diagrams result, as shown in Fig. 2, where the frequency ratios of 2:3, 3:4 and 4:5 are shown under a few representative phase conditions. Here it will be noticed that an inversion of the frequency ratio is equivalent to viewing the diagram sideways.

For the determination of the basic frequency ratio for any type of Lissajou figure, such as are shown

the illustrations, a simple rule for obtaining the frequency ratio, f/n, is to divide the number of times the trace intersects the horizontal axis (or any line parallel to this axis) by the number of times the trace intersects the vertical axis (or a line parallel to it).

In many cases where the ratio is not exactly an integer an effect is noticed that must be considered in the rigorous application of this rule: the shape of the figure changes continuously through a certain series of diagrams. Since an oscillogram is produced by a moving spot of light, the line does not move laterally as a whole and successive journeys along the path may each trace a distinct new line. The combination of screen phosphorescence and visual retentivity then makes the oscillogram appear as a number of separate and superimposed diagrams.

When the frequency ratio is not that of two small integers, the figure is quite complicated so that in order to apply the above rule, the following procedure is recommended: Increase the amplitude of the deflection along one axis until the spot travels beyond opposite edges of the screen. Then count the number of times the path of the spot crosses a line drawn anywhere at right angles to this lengthened axis. Then reduce this deflection to normal and increase the amplitude of the deflection along the other axis and count the intersections of the trace with a line drawn anywhere at right angles with the latest axis to be lengthened. This spreads out the pattern and there is less congestion to interfere with the count.

The second part of the problem is that of determining the rate at which the unknown varies from the true multiple relation. Variations of three or four cycles per second can usually be followed visually. If, as is usually the case when audio frequencies are examined, the pattern changes too rapidly for the eye to distinguish, other plans must be used. It is a characteristic of all of these figures that twice during each series the diagram is a line. At all other times it is a closed diagram and represents a rolled-up ellipse (see Fig. 12 of Feb. article).

It happens that the ends of one of these line diagrams (as distinguished from the closed loops) are brighter than the rest of the trace, as the spot momentarily stops there and reverses its direction. It is possible therefore to add a timing field in a third direction either by the application of a known timing wave to deflection coils so as to shift the whole diagram in some radial direction, or by the application of a circular time base in the manner described in connection with Fig. 38 or Fig. 45 in the April article. By thus translating the whole diagram it may be possible to count the brighter spots or streaks that occur at the ends of the lines, especially if the spot is somewhat defocused so that the normal diagram itself is not distinguishable. It also may be advantageous to reduce the intensity of the trace so that the spots only are visible. The net result is that every time a line diagram momentarily appears due to the two frequencies being in phase, a pair of bright spots will appear, and these spots are drawn out into a line, circle or ellipse so that they can be readily counted.

It will be necessary of course to know accurately the frequency of the auxiliary timing wave. Each dot represents a gain of one-half cycle of one wave over the other, but usually the dots will appear in two parallel lines if the direction of the auxiliary deflection is suitably chosen, so that each dot can be considered as a gain of one cycle. In order to prevent error the auxiliary timing wave frequency should be varied manually in intensity for a preliminary test. The purpose of this is to ascertain whether successive occurrences of the in-phase condition produce adjacent dots. Another test is to swing a permanent magnet past the tube and to note whether the rows of dots appear to shift as a line or break up as two or more lines.

FREQUENCY DETERMINATION WITH CIRCULAR DIAGRAMS[5,6]

When one frequency is an exact harmonic of the other, circular or elliptical diagrams are easier to analyze. In the April article an analysis of some of the results obtained with different circuits was made. A common arrangement has been to apply the unknown frequency in series with the anode potential, so that the deflection sensitivity is periodically altered. The normal deflection plate circuits are connected to the standard frequency through a rotator circuit so that a circular trace is obtained. Fig. 3 shows several diagrams that are obtained with different frequency ratios. These diagrams are self-explanatory and their interpretation can be made by counting the number of lobes and the number of times any radius vector cuts the curve.

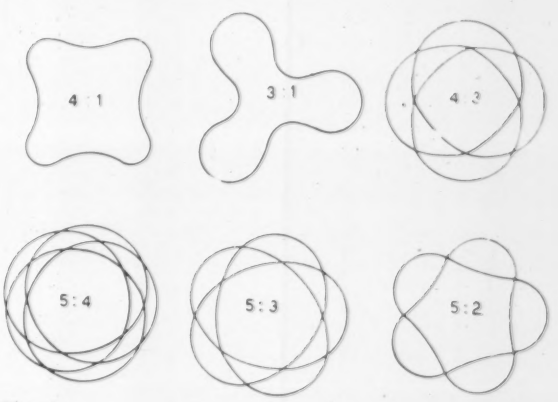


Fig. 3

Fig. 4

In the same article there was also described the double rotator circuit wherein both the standard and the unknown frequencies operate to rotate the spot (Figs. 46 and 47). The result depends upon whether these forces tend to aid or to oppose each other.[5,9,10] Fig. 4 shows representative oscillograms for certain frequency ratios, obtained by using this method. If the polarity of one pair of deflection coils is reversed, the diagram will change to the alternate style. Close inspection will show that when the cusps turn out (Fig. 4a) the gear has two more teeth than when they turn in (Fig. 4b).

Analysis of the circuit will show that both of the applied frequencies follow a circular path and that the higher frequency curve, in effect, rolls around the edge of the larger circle. If the two rotary movements are in

(Continued on page 264)

[5]Dye. The Cathode-ray Tube Method for Comparison of Frequencies. *Proceedings Physical Society*, Vol. 37, 1935, pages 158-168.

[6]Richardson. Time Marking with a Cathode-ray Oscillogram. *Proceedings Physical Society*, Vol. 45, 1933, pages 135-141.

[7]Richardson. Time Marking with a Cathode-ray Oscillogram Using Harmonics. *Proceedings Physical Society*, Vol. 47, 1935, pages 258-262.

[8]McGregor-Morris & Wright. Circular Time Base Giving Radial Deflections. *Journal Institute of Electrical Engineers*, Vol. 71, 1932, pages 82-85.

[9]Rangachari. Harmonic Comparison of R.f. Waves with the Cathode-ray Oscillograph. *Experimental Wireless & Wireless Engineer*, Vol. 5, 1928, pages 264-266.

[10]Rangachari. Analysis of Circular Diagrams. *Experimental Wireless & Wireless Engineer*, Vol. 6, 1929, pages 184-193.

A Method of Measuring A-c. Millivolt

By PAUL MacGAHAN

Meter Engineering Division, Westinghouse Electric & Manufacturing Co., Newark, N. J.

MILLIVOLTMETERS of the permanent magnet moving-coil type for direct currents are characterized by high watt sensitivity: one microwatt for full-scale deflection can readily be obtained in portable instruments of this type without impairing ruggedness. This is in strong contrast to the moving-iron or the dynamometer principles of a-c. instruments, which generally require one watt or more for full-scale torque. For example, a 1 volt a-c. voltmeter operating on the moving iron principle would require approximately one ampere full-scale current.

Rectifier type permanent magnet instruments, however, provide a low-energy means of measuring alternating currents, retaining the low-energy characteristics possible only with the permanent-magnet type. Instruments which contain a miniature full-wave copper oxide disk rectifier (known as "Rectox") are suitable for measuring certain comparatively low values of a-c. amperes or volts. However, a definite limitation is encountered in attempting to design a rectifier type voltmeter for the measurement of low voltages, *i.e.*, millivolts, due to the fact that the resistance of an element such as the Rectox is a non-linear function of the value of the current flowing through the disks, and is influenced also by the temperature. This necessitates the use of a resistance coil in series with the Rectox, such resistance being of a sufficiently high value to reduce to permissible limits the effect of these variables upon the accuracy of the instrument. In consequence of these limitations, Rectox voltmeters for a-c. voltages lower than 3 volts full scale have not been successfully produced.

To be sure, another reason why a-c. millivoltmeters have not been produced commercially is that their applications are neither as widespread nor as diversified as are the applications of d-c. millivoltmeters. Nevertheless, there are distinct fields of usefulness for an a-c. millivoltmeter. Its principal use is to facilitate measurement of drops in conductors, cables, circuit breakers, switches or control circuits carrying alternating current.

In the arrangement shown in Fig. 1, the twofold problem of fair accuracy and complete portability has been satisfactorily solved by placing a miniature step-up voltage transformer within the case of a Rectox portable instrument. This transformer is wound for a primary voltage of 30 millivolts and a secondary output of 3 volts.

Even with the addition of this transformer the energy required is far below that of portable alternating current instruments operating on other principles. Thus the input current required for the 30-millivolt range is 0.025 ampere, and the energy, therefore, is of the order of 0.00075 watts.

The instrument is not intended for use as an a-c. ammeter operating from a shunt as in the case of d-c. millivoltmeters.

The principle of operation involves certain inherent errors due to circuit wave-form variation, temperature, etc., which limit the applicability of copper oxide rectifier instruments to uses for which other principles are entirely unsuitable. Nevertheless, without making any pretentions to high accuracy, it is believed that the above-described method will prove to be a convenient solution of certain classes of problems involving measurements of drops in a-c. apparatus, etc.

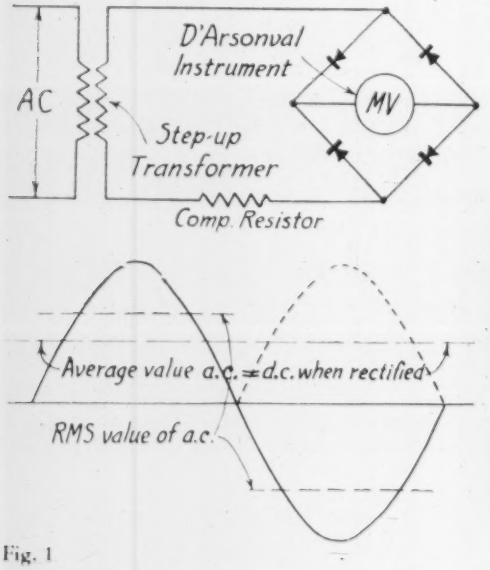


Fig. 1

Editor's Note. As we go to press the author informs us that (1) acknowledgement should be made of the valuable work done by U. L. Smith of the Westinghouse Co. in developing this method; (2) after our acceptance of this article an English anticipation of this method has been found: on page 176 of *Industrial Electrical Measuring Instruments* by Edgecumbe & Ockenden (Pitman & Sons, London, 1933).

Fig. 2 (slightly less than actual size). Showing scale law.

CHARACTERISTICS OF MILLIVOLTMETER

Amperes full scale	0.025
Resistance (low range) ohms at 60 cycles	1.2
Volts full scale (low range)	0.030
Torque full scale, mm.g	0.56
Weight of moving element, g	1.25
Moving coil copper resistance, ohms	78.
Temperature influence (A.I.E.E.)	3%
Energy full scale (0.030 Volts), watts	0.0008

Automatic Control of Voltage and Current

Thirty-third instalment of "Electrical Measurements and Control." This series began in the January 1934 issue. See announcement on editorial page of November 1933 issue. All rights reserved by the authors.

By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

5. Regulators with Static Sensitive Elements.

(Continued)

(b) Electron-tube Voltage Regulators.

The sensitivity and speed of response of electro-mechanical types of voltage and current regulators are definitely limited by friction and inertia of the parts; and, while these limitations may not be objectionable in many installations where large generating units are involved, yet the instantaneous action of the electron tube has rendered it of such value in regulation that, at the time of writing, one may foresee the whole field of automatic-control of voltage and current being dominated by electron tubes and their associated circuits. Electron tubes in their numerous forms possess other properties, and have been utilized for voltage and current control in so many ways that to describe, even sketchily, the many systems which have evolved and which are almost daily making their appearance would far transcend the limits of these pages.

The "threshold effect" of glow tubes and the non-linear characteristics of thermionic tubes form the underlying principles in many voltage-sensitive elements; and the relaying and rectifying properties of electronic devices, when used in conjunction with other forms of sensitive elements, further widen the applicability of electron tubes to the automatic regulation of electrical variables. The few methods which it is practicable to describe in these paragraphs can serve only as an indication of the unlimited possibilities of electron-tube control, and the reader in search of a true perspective of the field is referred to recent books[19,20] and to the ever-growing mass of material in scientific and technical journals.

"Glow Tubes" as Regulators.

The characteristics of the corona-discharge or glow tube make its critical voltage suitable for the constant element in a regulator. This device consists essentially of two electrodes sealed into a glass tube containing an inert gas at a suitable pressure. When properly designed, it has the characteristic that the voltage at which corona forms and the gas becomes conducting by ionization is practically independent of temperature or frequency. The fact that it is responsive to peak voltage rather than effective voltage is not a serious disadvantage on commercial supply circuits where the variation of voltage waveform is seldom appreciable. When the regulation of voltage of small generators is involved, however, variations of form factor under different conditions may be sufficient to render undesirable the use of the glow tube regulator.

The simplest application of the glow tube to voltage regulation is in some types of radio apparatus where a relatively small and steady current is drawn from a variable voltage source. A glow tube is connected in circuit with a tapped resistance between the supply and the load, and by its rapid change in current with relatively small voltage variation, is able to govern a varying fall of potential. This drop is combined in the regulated voltage in a manner to provide a reasonable degree of compensation for change in the supply voltage.

The limited current capacity of the simple glow tube places restrictions on its use as a regulator without some form of relaying device or circuit; but in conjunction with a grid-controlled gaseous rectifying tube (such as the G-E "Thyratron" or Westinghouse "Grid-glow") it can be developed into an effective combination for generator field control.[21] The rectifying property of

[19] Keith Henney, Electron Tubes in Industry. McGraw-Hill Book Co., New York, 1934.
[20] F. H. Gulliksen & E. H. Vedder, Industrial Electronics. John Wiley & Sons, New York, 1935; Chapter XV.
[21] H. W. Dodge & C. H. Willis, A Corona-tube Voltage Regulator. *Transactions A.I.E.E.*, Vol. 50, 1931, pages 1466-1468.

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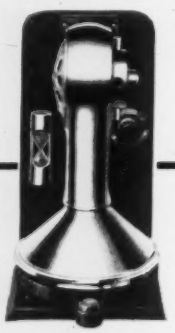

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a grid-controlled rectifier is definitely governed by the phase position of its grid voltage as related to its plate voltage, so that by delaying the grid the attaining of a critical potential in each cycle it is possible to control the value of the rectified current. As the phase position of a voltage may be controlled without appreciable expenditure of energy by various forms of primary measuring elements, the grid-controlled rectifier thus provides a flexible and effective relay for many schemes of automatic control, and has consequently found many applications in voltage regulation—seldom as the voltage-sensitive element proper, but chiefly as one of the links whereby the variations are made to command the final controlling member of the system.

By charging a grid-biasing condenser through a glow tube, the amount of charge, and hence the time of discharge, in each cycle may be made to vary widely for a small variation of voltage in the neighborhood of the critical value for a tube. Such a circuit, connected to the grid of a grid-controlled gaseous rectifier, may thus be made to control the rectified current derived from the latter; and this current, passed through the field circuit of a generator or exciter, makes possible an extremely precise and rapid control of voltage.

Thermionic Tubes as Regulators.

The principal properties of thermionic tubes which may be utilized in providing voltage-sensitive elements for automatic regulation are the large change of plate current in response to variation in grid bias and the sensitivity to changes in filament temperature of a tube operated at "plate saturation." The use of the former property in a-c. regulation involves rectification of the voltage and its opposition to a fixed voltage in the grid circuit, the changes in the differential or residual potential being utilized to control the output of the tube, which may be variously used in governing field excitation. The system is thus inherently suited to d-c. regulation, and to some extent has been used for this purpose. In general, the need for rectifying the voltage before measurement has led to the use in a-c. work of the tube operating at plate saturation, and a number of practical regulators using this principle have been devised. A three-electrode tube is not required where the output is controlled by filament temperature, and in some regulators using the principle there is employed a triode having the grid directly connected to the filament. In others, a resistance between the two enables a certain degree of anti-hunting to be incorporated in the system.

An extremely simple voltage control devised some years ago by Stoller[22] and particularly suited to the control of voltage under widely varying speed conditions, has found considerable application in connection with small wind-driven direct-current generators. The generator is provided with two opposed field windings, a main winding in series with the filament of a two-electrode tube, and a differential winding in the plate circuit. At minimum speed the differential field is inactive. As the main field current tends to increase it heats the filament, allowing an increased plate current to flow in the differential winding. This current tends to reduce the field flux, thus restricting the rise in voltage. Because of the rapid variation of the plate current with changes in the filament current, this control can be made highly sensitive, and on small generators it has been found possible thus to maintain the output voltage within 3 percent through a 300 percent change in speed.

The property of "plate saturation," as described in the foregoing example, provides regulation over a range of speed, but is not inherently sensitive to variations of the voltage itself. The basic principles of voltage regulators utilizing plate saturation in the sensitive element and acting to control generator fields in response to voltage changes, are outlined in a detailed discussion published by Verman and Richards.[23] They involve conversion of the fluctuations in the a-c. voltage into direct current, which is effected in a tube operating at saturation; amplifying these; and applying them to the field of a generator or exciter. The interconnecting circuits may employ electronic or other relay devices; but the gaseous conduction tubes such as the "Thyratron" or "Grid-glow" have enabled the capacity of such regulators to be extended to relatively large units.[24,25]

[22] E. B. Craft & E. H. Colpitts, Radio Telephony, *Transactions A.I.E.E.*, Vol. 38, 1919, pages 305-343.
H. M. Stoller & J. R. Power, Precision Regulator for Alternating Voltage, *Journal A.I.E.E.*, Vol. 48, 1929, page 110.

[23] L. C. Verman & L. A. Richards, A Vacuum-tube Voltage Regulator for Alternators, *Review of Scientific Instruments*, Vol. 1, Oct. 1930, pages 581-591. Also: L. C. Verman & H. J. Reich, A Vacuum-tube Voltage Regulator for Large Power Units, *Proceedings Institute of Radio Engineers*, Vol. 17, 1929, page 2075.

[24] F. H. Gulliksen, Electronic Regulator for A-c. Generators, *Transactions A.I.E.E.*, Vol. 53, 1934, pages 877-881.
Discussion on above: *Transactions A.I.E.E.*, Vol. 53, 1934, pages 1530-1531.

[25] C. E. Weinland, A Thyratron Voltage Regulator for an Alternator, *Review of Scientific Instruments*, Vol. 3, Jan. 1932, pages 9-19.

A practical embodiment of the purely electronic regulator is found in the recently introduced Ward-Leonard "Type EF" generator voltage regulator[26,28] shown in Figs. 48-22 and 48-23. Referring to the diagram, it will be seen that the exciter field current is derived from a full-wave rectifier having two recti-

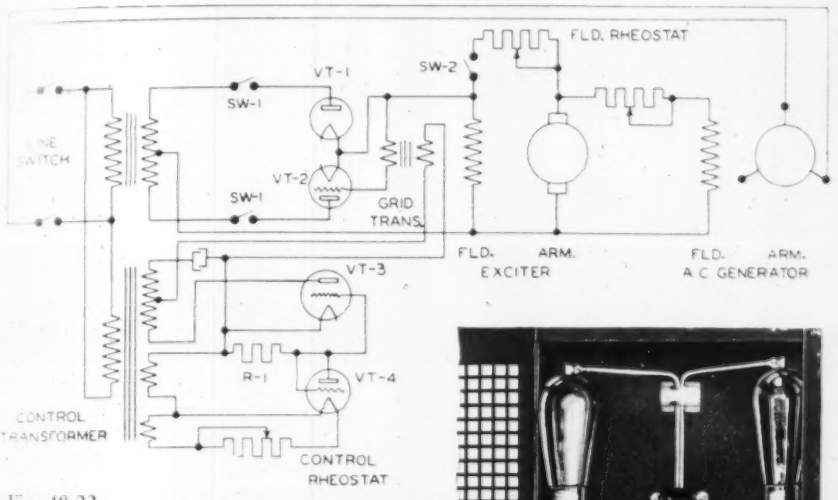


Fig. 48-22

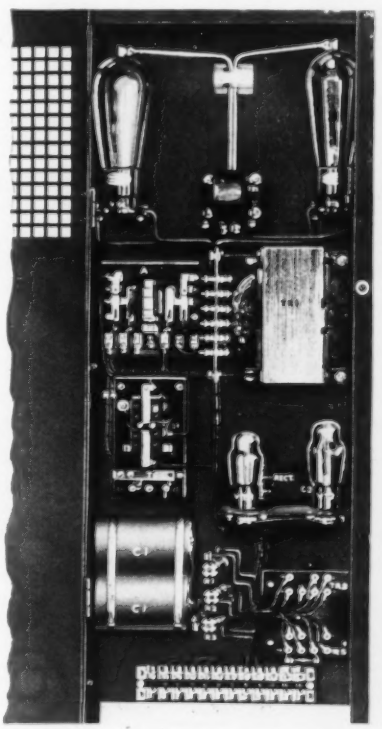


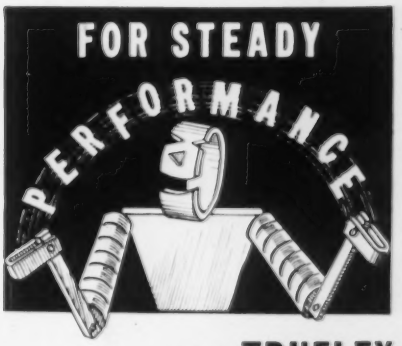
Fig. 48-23

fying tubes *VT-1 and VT-2*, the output of the latter being controlled by the phase position of its grid voltage. The tube *VT-4* operates at plate saturation, so that relatively small variations in filament current, derived from the source to be controlled, produce great changes in the negative bias voltage applied to the grid of tube *VT-3*. This tube functions much as a rheostat in the anode circuit of tube *VT-2*, and acts in conjunction with a capacitance to vary the phase position of its grid voltage, thereby controlling the total output of the rectifying circuit which feeds the exciter field. The diagram includes a switching arrangement whereby the system may be placed in service as a self-exciting unit, and control shifted to the electronic regulator as normal operating conditions are attained.

The Westinghouse "Type AT" electronic regulator provides an example of the type in which the sensitive element is a rectifier tube having a non-saturated filament or cathode. The d-c. output voltage of this rectifier is proportional to the average value of the a-c. voltage applied to the anodes of the tube, so that the regulator tends to maintain constant the average, rather than the r.m.s., value of voltage. The principle of operation may be understood by reference to Fig. 48-24. The generator voltage 1-2 is rectified by means of No. 1 high-vacuum full-wave (RO-587) tube, whose d-c. output is filtered and applied in opposition to a 90-volt battery B. The voltage difference between the rectifier tube and the battery is amplified in a two-stage amplifier consisting of Nos. 1 and 2 screen grid amplifier (RJ-571) tubes, and applied to a phase-shift circuit which controls the current through four grid-controlled mercury vapor (KU-628) power tubes which are connected in the exciter field circuit. An auxiliary circuit supplied with line current at the terminals 3-4 provides an adjustable compensation for load and line conditions.

The Westinghouse Type AT-1 regulator is similar to the AT, except that it makes use of a saturated tube, and thus regulates to a constant r.m.s. voltage value.

[26] U.S. Patent No. 1,982,007. F. G. Logan, Nov. 27, 1934.
[27] U.S. Patent No. 1,997,179. F. G. Logan, April 9, 1935.
[28] U.S. Patent No. 2,003,945. F. G. Logan, Sept. 5, 1935.



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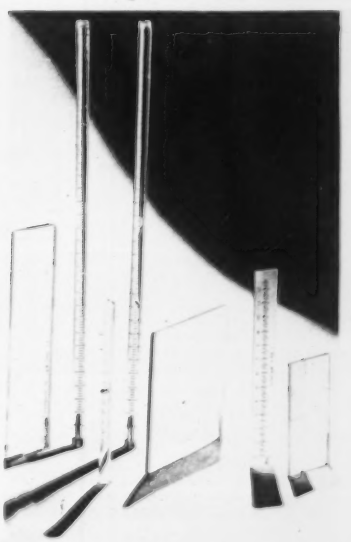

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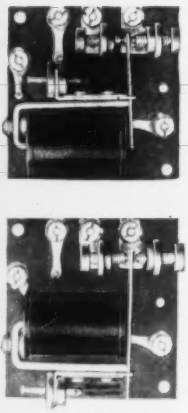

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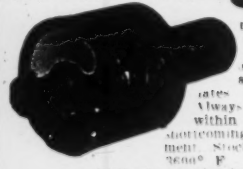

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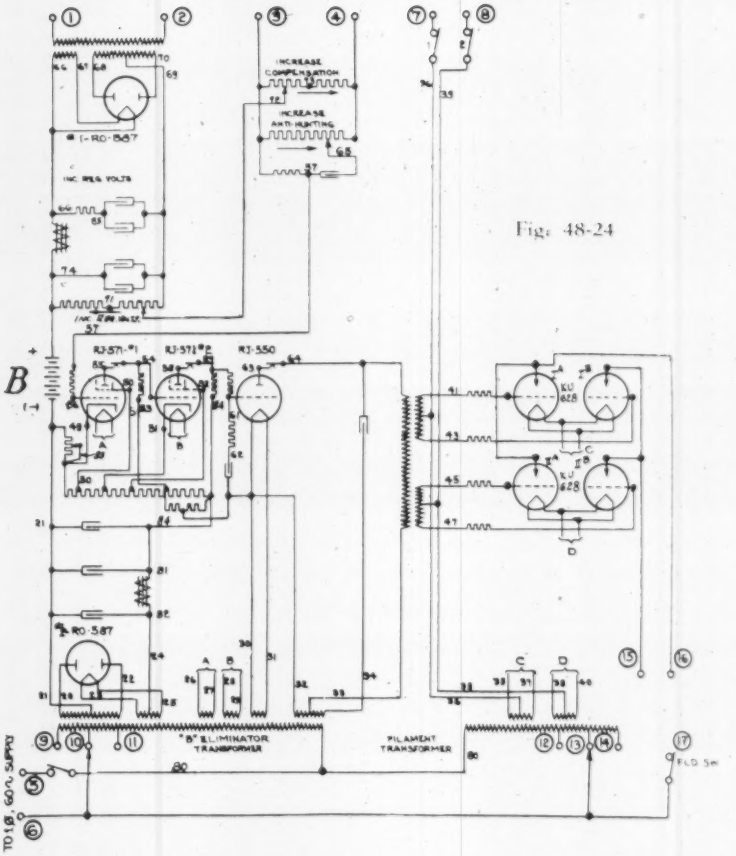

Fig. 48-24

There has recently been announced[29] a Westinghouse electronic regulator which is essentially a greatly simplified form of the above, using a "saturated" tube and providing against tube failure. As may be seen from the schematic diagram, Fig. 48-25, this regulator is fundamentally a grid-controlled full-wave rectifier, consisting of tubes T_1 and T_2, supplying rectified current to the generator field. The grid control is obtained through the action of diode T_3 whose

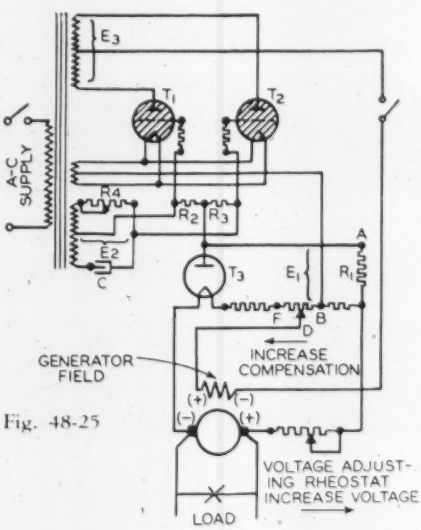

Fig. 48-25

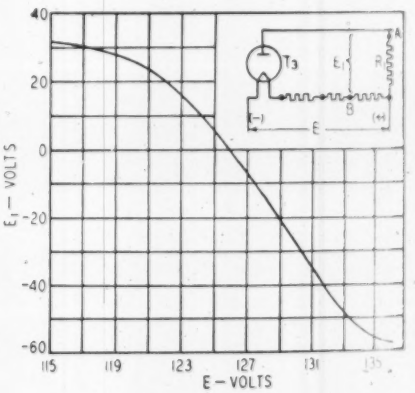

Fig. 48-26

anode current is a function of the generator armature voltage. In this tube the current between anode and cathode is a function of the cathode temperature, hence of the cathode current (see Fig. 48-26). Thus, the voltage E_1 between A and B, bears such a relation to the generator voltage that at the control point (say 125 volts) the relative polarity of A and B is reversed. Drooping characteristic is minimized by passing the generator field current through part of the resistor connected in series with the cathode of T_3, and hunting is prevented by the slight delay in this compounding action due to the inductance of the generator field winding.

[29] F. H. Gulliksen, An Electronic Regulator for D.c. Generators, *Electrical Engineering*, 55, 1936, pages 873-875.

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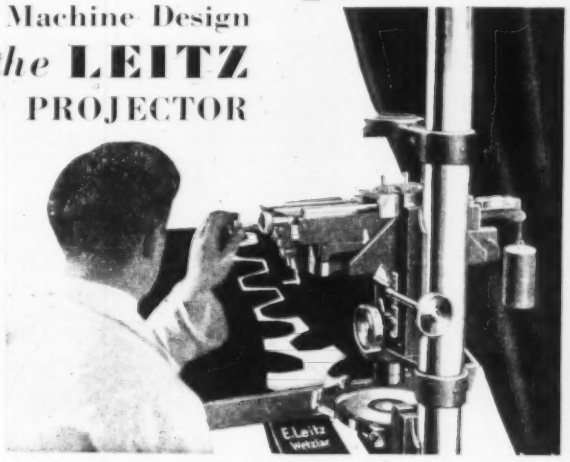

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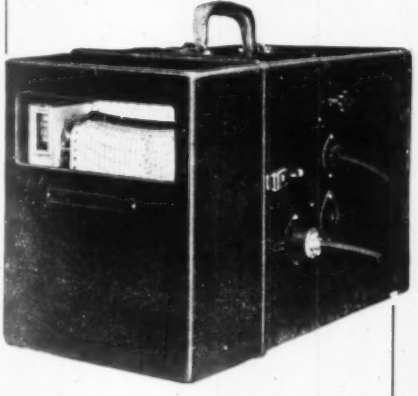

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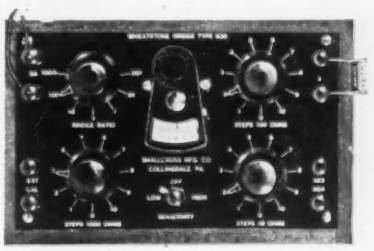

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OSCILLOGRAMS

Concluded from page 257

the same direction it takes two more cycles to complete the revolution than when the waves travel in opposite directions. Therefore if the cusps turn "in" the frequency ratio is equal to $(X + 1)$ where X is the number of cusps, and when they turn "out" the frequency ratio is $(X - 1)$. The amplitude of the unknown wave should be relatively small, in order that the diagram should not be needlessly complicated.

These curves represent a visual demonstration of the beats produced by combining two commensurate frequencies. The basic frequency, applied to the time base, rotates the spot in one direction. The other frequency, applied to the special circuits described, also tends to rotate the spot. If the rotations are in the same direction the total speed equals the sum of individual speeds; the opposite is true if the connections are reversed.

This effect need not give any difficulty as to the proper method of analysis. A simple check is as follows: If the higher frequency potential is removed the trace will retain its circular or elliptical shape. If the lower time base frequency is removed instead, the spot will either (1) remain stationary, (2) move in a smaller circular or elliptical path of its own, or (3) move in a straight line. In case (1) the frequency ratio is the same as the number of the teeth in the gear. In (2) the frequency ratio is either one unit greater or one unit less than the tooth ratio as explained above. In (3) the difficulty of correctly counting the number of teeth will prevent an accurate analysis, as explained in connection with Fig. 40b of the April article.

FREQUENCY AND TIME STUDIES WITH DISCONTINUOUS DIAGRAMS

If the cathode-ray tube has an auxiliary control provided for the purpose of focusing, modulating or blocking the ray, frequency comparison utilizing a discontinuous pattern can be made. This grid also provides a means for measuring extremely short intervals of time.

As explained in the Oct. 1935 article, this grid forms a shutter whereby the brilliance of a spot can be partially or completely extinguished. In the present types of RCA tubes a potential of about 3% of the anode voltage is sufficient to shut off the electron stream.

The circular time base,[6] produced by a known frequency, is used as before. The unknown wave or pulse is applied to the modulating electrode to alter the normal brilliance or focus of the spot. The resulting pattern is a series of dots, which can be counted to give the frequency ratio. It may be necessary to test out to determine whether two adjacent dots represent successive cycles. If the frequency ratio happens to be non-integral, the dots or pulses of light projected during the second revolution may fall between those of the first revolution. A simple test for this effect is to move the whole diagram laterally, and fairly rapidly, as by swinging a permanent magnet nearby. If the dots move as a line, the frequency ratio is the integer represented by the count of the dots on the time base cycle. If, however, alternate dots move different amounts and the line seems to break up into two or more rows, the frequency ratio is an improper fraction equal to the total number of dots divided by the number of rows. This arrangement makes an excellent method for checking the ratio of the input and output frequencies of a multi-vibrator oscillator circuit.

A synchronous motor driving a commutator equipped with a number of sectors will provide a standard timing pulse circuit for this type of test. Devices can be used which utilize a magnetic "hummer," made by rotating a steel gear wheel so that its teeth pass by the pole of an ordinary telephone receiver.[11] The output of the 'phone is amplified and used to modulate the electron stream. The use of a synchronous motor driven from commercial a-c. supply mains (in districts where the system frequently is well regulated) provides a series of pulses of sufficient accuracy for most tests.

[11] Sundt & Fett, New Timing Method for Cathode-ray Oscillographs, *Instruments*, Vol. 7, 1934, page 156.

AMENDMENTS TO SPECIFICATIONS FOR LIQUID-MEASURING DEVICES

Adopted by the Twenty-sixth National Conference on Weights and Measures, Jan. 9-12, 1936, Recommended by the National Bureau of Standards for Adoption by the States

Amend the second paragraph of Specification 6 to read as follows:

A special elapsed-time test shall be made to determine whether the device is satisfactory with respect to condition (3) above. In order to comply with this test the condition of the device shall be such that the error due solely to the nonuse of the device does not exceed 2 cubic inches per hour in the case of a retail device and 5 cubic inches per hour in the case of a wholesale device: Provided, however, That in the case of a new device the permissible errors shall be one-half the values given above.

Amend Specification 8 to read as follows:

A liquid-measuring device in which is incorporated a computing mechanism which indicates the total price of the amount of commodity delivered, for one of a series of unit prices, shall also be equipped with a unit price mechanism by means of which the unit price at which the total price is being computed at any time shall be displayed on each face of the device.

Amend Specification 34 to read as follows:

Return of Indicating Element to Zero.—Retail devices shall be so designed and constructed that the indicating elements used to tally sales and deliveries to individual purchasers or to indicate the amount delivered when any portion of the cycle or stroke has been completed, or the total price thereof, shall be returnable readily to a definite and clear zero indication before the next delivery is begun. *Means shall be provided to prevent the indicating element from being returned beyond the zero graduation. The indicating elements may be advanced only by the mechanical operation of the device itself*: Provided, however, That the device may be cleared by advancing the indicating elements to zero but only when the means employed automatically results either in a movement that can not be interrupted or in an obscuring of the registration, until the zero position is reached.

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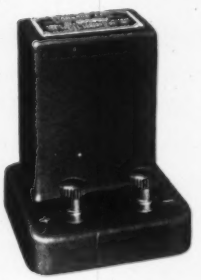

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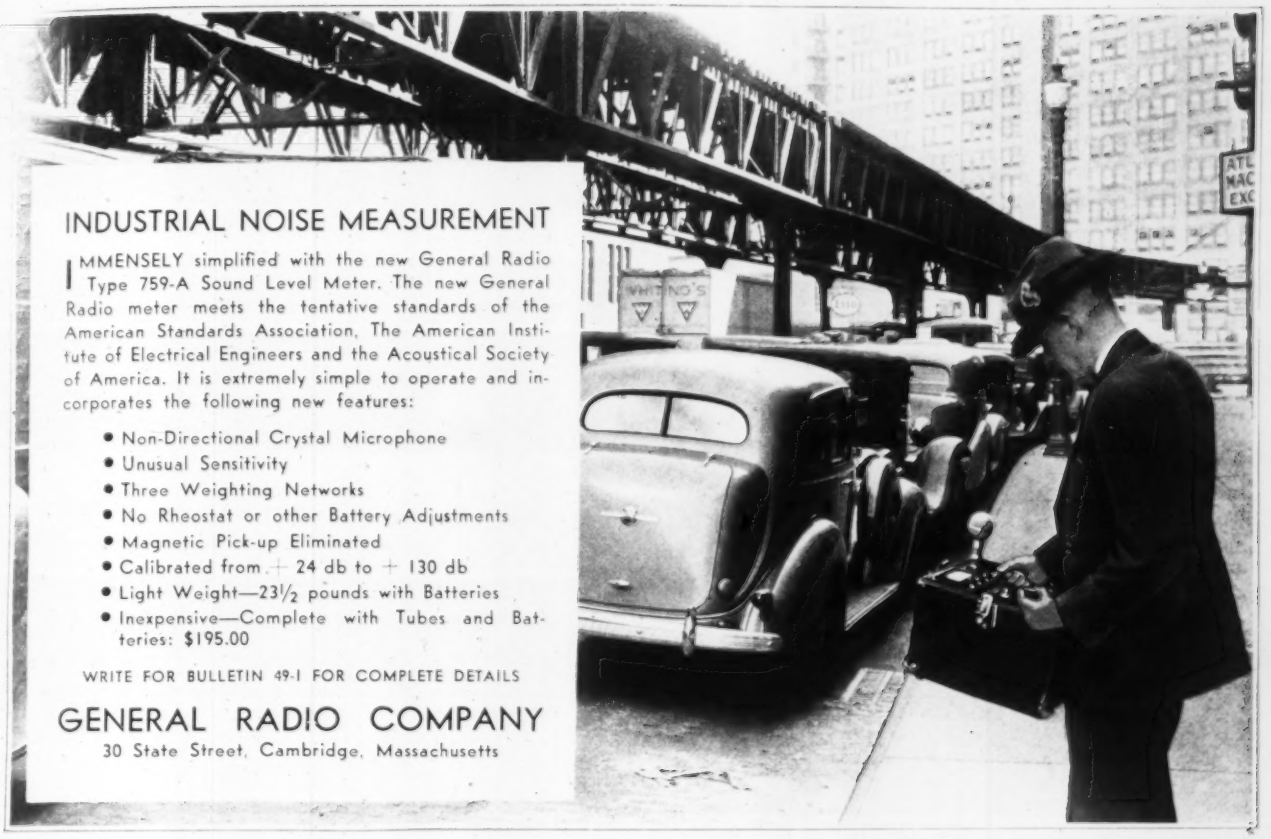

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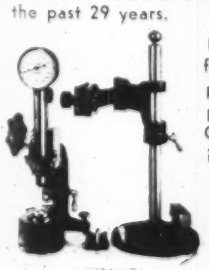

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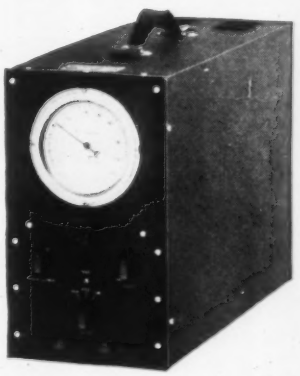

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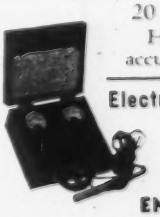

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